

THE COMPLETE
**.50-CALIBER
SNIPER COURSE**

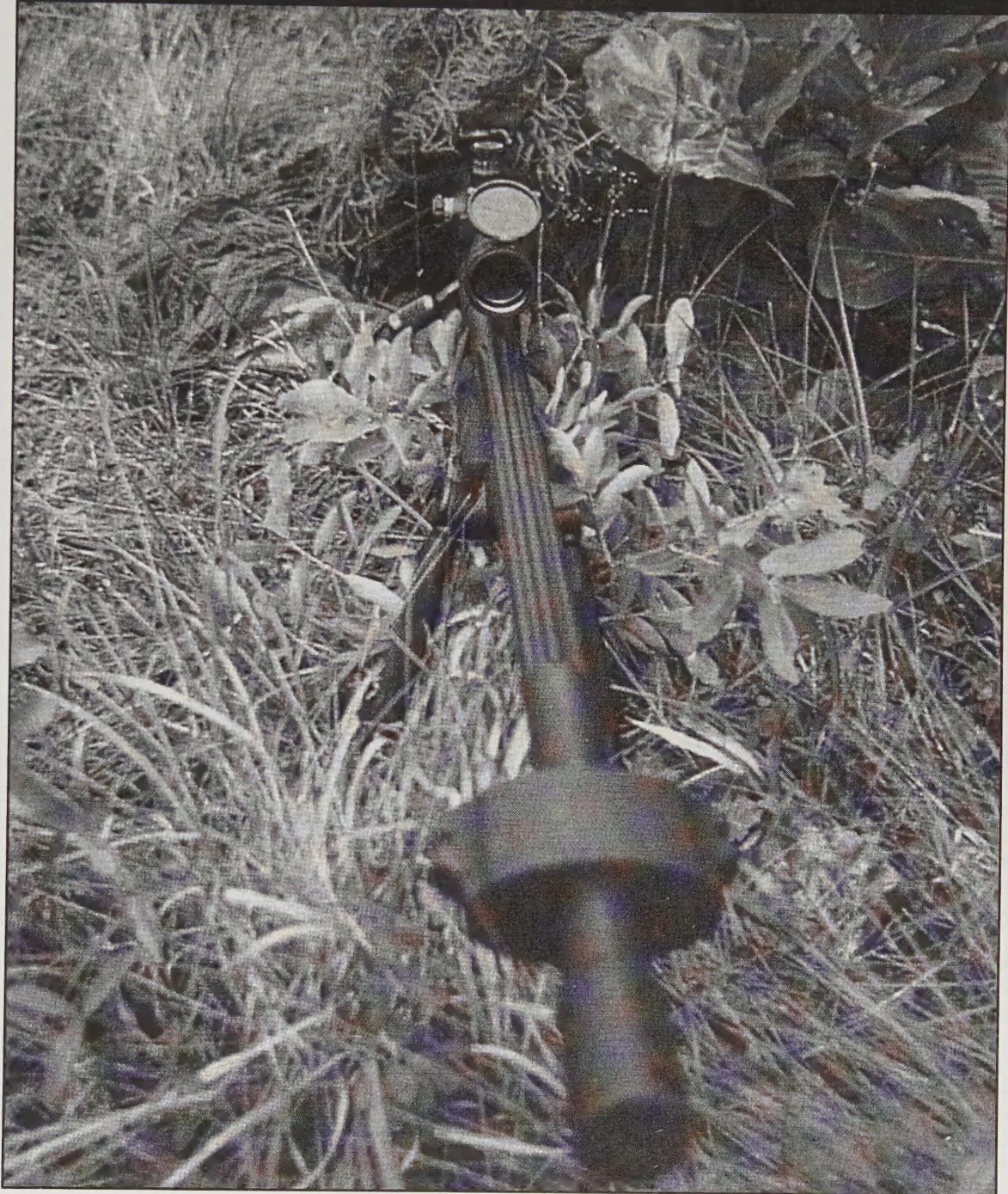


HARD-TARGET INTERDICTION

Dean Michaelis

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The Complete .50-Caliber Sniper Course
Hard-Target Interdiction
by Dean Michaelis

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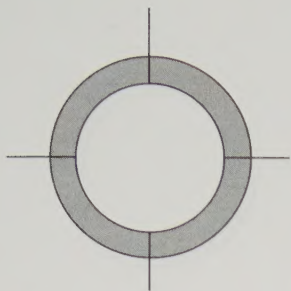
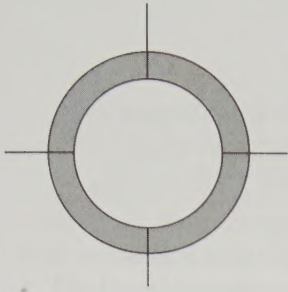


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Preface

Hard-Target Interdiction (HTI) is a branch of military sniping that began in the 1930s. The large-bore, heavy caliber guns were designed to halt British armor. The sniper rifles, known as the heavy class of guns, are .50-caliber and larger in size, and while they are called sniper rifles they are more accurately described as low-angle trajectory, direct-fire artillery pieces. I say that because the HTI teams make corrections for meteorological (MET) and environmental (ENV) conditions that military snipers only make gross corrections for. HTI operators use scientific calculators and correct for the same conditions that field artillery ballistics computers do.

This book was written as a result of the author's entry into the heavy-class training arena in 1984, the year when .50-caliber rifles began showing up in special operations in limited numbers and of questionable quality. The details of this strange procurement and testing process are covered in the first chapter in this book. Since that initial entry, much data and training experience has been developed. Much of the material presented here is the result of hundreds of hours on a scientific calculator (one which is capable of geometric, trigonometric, and angle functions) and even more hours behind the guns themselves.

Weapons that are used in this class of operations are the heavy guns. This class of rifle starts at the .50-caliber Browning machine gun (BMG). The operational environment known as HTI is basically defined this way:

Hard-Target Interdiction is the practice of engaging materiel-type targets that are considered theater strategic assets. Eliminating targets in the HTI mission scope would have a great impact on the ability of the enemy to wage war or defend itself against further strategic targeting.

The HTI class of targets can be paraphrased into the following:¹

- Shooters not shooting
- Emitters not emitting
- Movers not moving

It is generally assumed that a sniper trained to engage soft targets to a range of 800 meters has sufficient training to allow that same shooter to engage materiel targets at ranges of 2,000 meters. However, years of experience, training, and gun time have proven this to be untrue. Current thought in the military is that when someone graduates from the sniper program (U.S. Army Sniper School at Fort Benning, GA; the U.S. Army's Special Operations Target Interdiction Course (SOTIC) at Fort Bragg, NC; the U.S. Navy SEAL

sniper programs at Naval Surface Warfare (NSWG-1 and NSWG-2); and the U.S.M.C. Scout Sniper Instructor Course at Quantico, VA, he is ready to shoot the rifles that would fall into the heavy class.

Based on my experience I have come to the conclusion that only about two out of ten 7.62mm-class shooters that could normally engage 100 percent of their targets out to a range of 600 meters could shoot the .50-caliber rifles with any degree of accuracy. I have seen personnel introduced to the rifle that had never shot a .50-caliber or a precision weapon before. But with a 5-minute period of instruction they were able to hold the weapon from 1.5 minutes of angle (MOA) to 2.0 MOA.

It is a little-known fact that there is no specialized training offered on the heavy-class rifles. However, the U.S. Navy SEAL program goes in the right general direction. They shoot a lot of ammunition and are religious about recording their data into a shooter's log. But this does nothing for deploying you and your rifle to a location anywhere on the earth and placing first- or second-round engagements on HTI-type targets.

In the HTI environment you are, for example, engaging a target at a range of 1,500 meters using .50-caliber, Mark 211, Mod-0 or Raufoss ammunition. The firing tables that are available list the initial elevation setting at 78.50 MOA for 1,500 meters. If the air temperature were 80 degrees instead of the standard of 59 degrees, the round, if uncorrected would impact 51.72 inches above the point of aim. This is with the small variation in air temperature. When you add the likelihood that the barometric pressure, ammunition temperature, and possibly the angle to the target are all not standard, the chances for error are high.

Many countries have bought .50-caliber rifle systems for their military. Of the various optical sight systems they have used, a good example is the Barrett "Christmas tree" reticle pattern used with the Barrett light .50 caliber. The reticle pattern is calibrated for M33 Ball ammunition under standard atmospheric conditions. I refer you to the previous example. If you were shooting in the Middle East or Yakima, WA, the conditions there can easily be 110 degrees Fahrenheit, 27.55 in. Hg (inches of mercury, the unit of measure for barometric pressure), an ammo temperature of 120 degrees, and a slant angle of 30 degrees. If these conditions are not calculated for, a terrible error will occur.

This book contains all the key training ingredients for successful long-range heavy rifle engagements. This book is intended to allow someone to deploy his rifle anywhere in the world, under any MET or ENV conditions. He will learn to calculate for these conditions and place the corrections on the optical or iron sight on the rifle. He will fire his first shot and strike his target. For the student ballisticians out there, this is a truly practical application for the ballistics discipline.

I would like to acknowledge all the unnamed snipers and operators for their support in the years that this program traveled its rocky road to development. Along the way, the program has picked up its share of supporters and has lost a few, too. I would like to specially recognize two snipers and very fine individuals. The three of us ran the first HTI course specifically designed to engage materiel targets with heavy caliber guns using the methods in this book. Maj. Eugene Econ and Staff Sgt. Bruce Bevans are two individuals that spent many long days and nights training the snipers of the 1st Special Forces Group (Airborne) during part of 1995 and 1996. I thank these two individuals: Through their tireless efforts, we ran a course that resulted in a vast part of the imagery in this book.

—Dean Michaelis

FOOTNOTES

1. We used these phrases to put "go words" into our briefing on HTI. The Air Force uses the term HTI to describe missions attacking weapons platforms such as ballistic missiles, radars, etc. The problem is that for them to detect these systems, they either have to be shooting (missiles), emitting (radar), or moving (mobile missile systems). This isn't always the case, but it frequently is. When we say shooters not shooting, this could mean anti-aircraft gun systems that can be destroyed by .50-caliber gunfire by teams that are on the ground and can visually locate these systems because they haven't exposed themselves yet to aircraft. These

PREFACE

would be pre-emptive strike missions and covert in nature. Shooters not shooting could also mean ballistic missile systems (SCUDs) that are not exposed to aircraft or satellite detection, yet the human operator on the ground will find them.

Emitters not emitting generally means radar systems, radio communication vans or other communications systems that can be reduced with heavy rifle fire. The Air Force can't use a HARM missile against a radar until that radar lights up. There is a good example of this in Chapter 11, "Target Analysis."

Movers not moving refers to a situation in which a stationary target is more difficult to detect by sophisticated air platforms. The targets can be found and engaged in their camouflage by HTI teams that are roving and searching for them. Again, the mobile SCUD launcher system is a good vehicle to use for an example when addressing movers not moving.



Military History of Hard-Target Interdiction and Its Development in Special Operations

The history of HTI within special operations (SO) is a little sketchy at times. This is true with many of the procurement aspects within SO—certain units have emergency purchasing powers to cover sudden regional emergencies, which can lead to a piece of equipment being introduced with no planning for training. It is a colorful history, and one filled with personal opinions made from within the SO community on which gun should be bought, built, or tested, and arguments over which gun should be considered the first of its kind or the official gun to use. There is and always has been a fair amount of interservice arguing over which gun is better. This is understandable because one service (the U.S. Navy) has considered themselves on the leading edge of this procurement battle. This is true for the most part. The Naval Special Warfare people have always had an interest in the heavy-class gun, while the Army Special Operations interest faded in and out.

HISTORY LESSONS

There are a couple of other problems dealing with tracking the history of anything within special operations. While a vast majority of the operations, weapons, and equipment are not classified; many of the procurement methods are somewhat kept quiet. This is done to keep potential vendors from gaining an edge in the contract phase of a program. A more low-level reason is to protect individuals from exposure due to bad decision-making on a system. As you will see later, some of these emergency procurement programs have caused shockwaves that continue to this day. This is absolutely the case with the heavy class of rifles. Spin-offs occurred from these fast procurement programs. The U.S.M.C. attended a small “unofficial” test with the U.S.M.C. Marksmanship Unit and consequently requested a number of Haskins .50 caliber rifles for the 22nd MAU (Marine Amphibious Unit).

Early Bolt-Action Rifles

Some of the earliest uses of bolt action rifles for materiel interdiction can be traced back to World War I. The British Army introduced the tank to the battlefield during that war and the Germans developed what

they thought was a counter to the tank. This rifle was the Mauser T-Gewehr (Tank Gun). The gun was a 13mm rifle based on an enlarged Mauser action (sounds like the new AWT from Greece). There was a muzzle brake fitted to the barrel and a pistol grip mounted behind the action. Initially, the 13mm cartridge had enough energy to do the penetration job, but it was soon made obsolete by developments in armor.

The 13mm gun was also used as a countersniper rifle. As is usually the case in warfare, an escalation of weapons and techniques brought these heavy guns to the battlefield. The Germans used steel plates to protect their snipers, who looked through small holes in the plate that proved very difficult for the allied snipers to shoot through. The allies suffered serious casualties in the war during 1914-'15 because of these measures. The British Army's solution to this

Right: Hard-target operators, Yakima, WA, 1996.

Below: The original PTRD 14.5mm rifle.



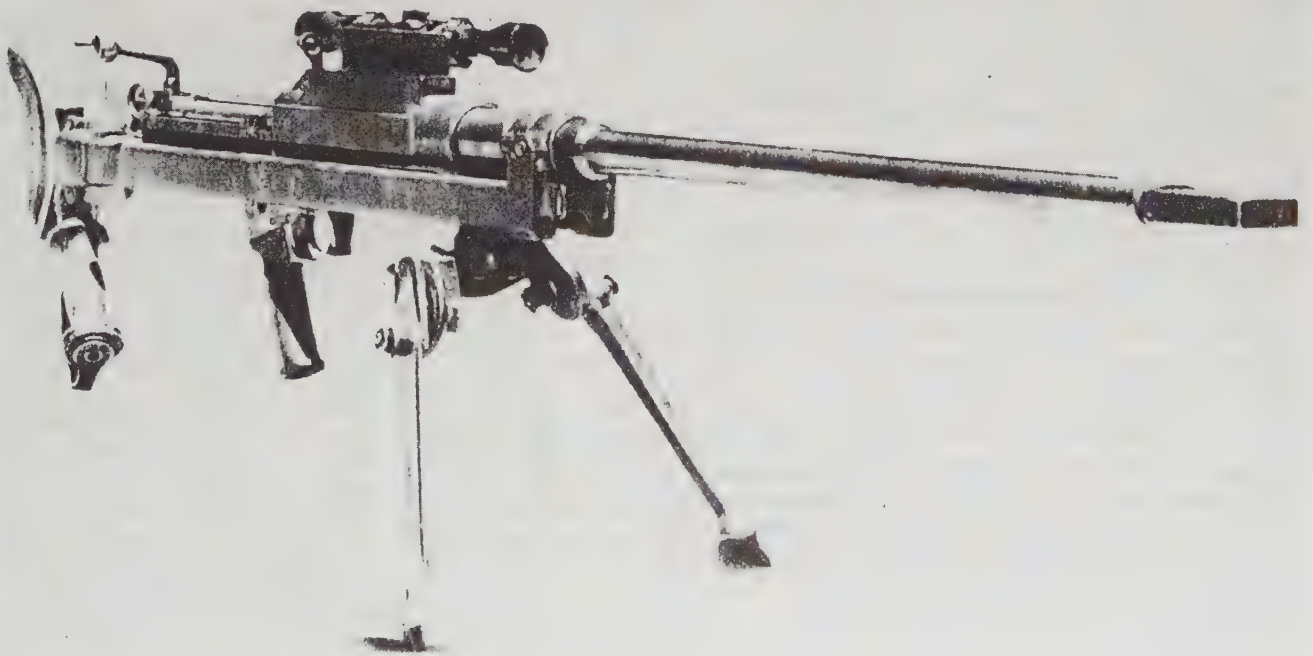
problem was to bring large-bore big-game guns from the African continent. They used the heavy slugs to smash down the plates, hoping to penetrate through to the sniper on the other side.

The German Army at this time started to use the 13mm gun to penetrate the steel plates of the allied snipers. Imagine the shock as these heavy projectiles came smashing through destroying both man and equipment.

The Next Generation

Between World War I and World War II, a couple of other anti-materiel rifles were introduced. The first of these was the Soviet PTRD anti-tank rifle. That rifle introduced the 14.5 x 114mm Soviet cartridge that was eventually used in the Soviet KPV Heavy Machine Gun. This gun fires an armor-piercing incendiary round (among others) that weighs 930 grains and has a muzzle velocity of 3,230 fps—very high energy even by today's standards. The PTRD anti-tank rifle was rendered ineffective for tank killing by the German armor of World War II. The gun chassis, however, hardly ended there. Eventually, the PTRD would become a test bed for the .50 caliber rifles used in Korea, but more on that later. As you can see in the picture on page 2, there isn't too much cosmetic difference between the PTRD and the M600 14.5mm guns. They are both skeleton-framed rifles, but you have to admit the newer gun looks a bit more of a pleasure to shoot. A critical difference also is the fact that the barrel on the M600 is freefloating, while the bipod on the PTRD rifle is attached directly to the barrel. This method doesn't lend itself to high accuracy, but high precision wasn't the name of the game—penetration was. With the armor of the time, if the steel could be penetrated, it had to be done at less than 400 meters or so. Of course, this depended on the blend of the steel and the angle of attack of the projectile.

Another rifle developed at that period was the German Army anti-tank rifle known as the PzB 38 (Panzerbuchse Modell 1938). The PzB 38 was self-ejecting and was rendered obsolete quickly by the rapidly advancing methods of armor in World War II. The PzB 38 became a single-shot manual action gun called the PzB 39. While the PzB never really worked very well as an anti-armor rifle during World War II, it later was the basis for much testing in the United States when they were rebarreled in .50-caliber BMG. The PzB was a



Boys .55-caliber anti-tank rifle as converted to .50-caliber BMG.



Col. Frank Conway behind the German .50-caliber PzB 39 anti-tank rifle.

13mm necked down to 7.92mm, which gave it fairly good penetration and velocity. That only works to a point, however. One interesting feature of these guns is that the weight of the PTRD and the PzB are within a couple of pounds of their current-day configuration weight. They really haven't changed all that much except for being made with better materials and technology.

Yet another rifle created in the 1930s was the Boys rifle, named after its designer, Capt. Boys. The Boys rifle was a .55 caliber bolt action rifle that was fed by a top-mounted magazine. The barrel and breech recoiled along a rail. The original .55-caliber gun is said to have had tremendous recoil, which was one of the prime reasons for the gun not seeing much combat use. The rifle did and still does set the basis for remanufactured long-range sniper rifles.

Post World War II

Colonel Frank Conway was assigned to Aberdeen Proving Grounds as a civilian after World War II. He knew





The .50-caliber flechette rifle based on the Boys anti-tank rifle.

the shortfalls of the .30-caliber round for sniping based on his previous experience. Conway is considered the originator of intentionally modifying anti-materiel rifles for anti-personnel use. Since that time, they have come a kind of full circle, as the big guns are now used mostly for anti-materiel. Late in 1946, Conway began the process of modifying a PzB 39 for the .50-caliber machine-gun barrel. The modification process took a full three days to complete and included the following modifications:

- Adapting a .50-caliber BMG barrel to the receiver.
- Moving the bipod forward to the end of the barrel for added stability.
- Adding a double baffle muzzle brake.
- Mounting a 3 x 8 telescopic sight borrowed from a German towed gun over the receiver.

The modified rifle weighed about 46 pounds. Conway said "Recoil was never a problem, but with that muzzle brake, ear protection was highly recommended." As has always been the case with sniper-weapon systems and at times snipers in general, there was little interest in the system, although it was successful. Ammunition has always been a problem with the heavy guns. Only within the last 10 years or so has there been an active effort to get high quality ammunition in the field. It's still not all there. Conway recalled his own ammunition problems: "Ammunition was always a problem, not because of a lack, but rather quality. Some bullets were mis-aligned with the case to the extent that when rolled on a flat surface, the nose of the bullet would rotate through a 1/4- to 3/8-circle. The fact that they could be fired at all speaks well for the big Brownings. I was fortunate enough to secure small amounts of satisfactory ammo packed in 10-round cartons for the .50 PzB."

During live-fire testing of the PzB at Fort Bliss, Texas, in the 1950s, success was achieved at ranges up to 1,400 yards. When the ART scope was being developed and tested, Conway tested the feasibility of using the ART scope on the PzB. A 4 – 12 X version with a ballistic cam curved for a range between 600 and 1800 meters was fitted to the PzB. According to a report, the target used in a test was the Army "E" shaped silhouette, which is 19.5 inches wide. The shooter was instructed to search the area for an unknown distance target and then fire three rounds. He was to dial the power setting down to 6X between each shot. The shots formed a triangular shape on the target 10 inches wide and 4.5 inches high.

The PzB was slated for field testing in Vietnam. The gun was fitted with a 6 – 18X Redfield scope. No one seems to know for sure if any of the guns made it over there. Certainly the .50-caliber machine gun was adapted for use, but why not have the real thing? No one really knows why. The big rifles went into a box for lack of command interest.

SNIPER RIFLE DEVELOPMENT

While snipers in Vietnam were struggling with the modification to the .50-caliber machine gun for sniping and the modified PzB was scheduled to go (though it never did), an organization called Defense, Advanced Research Projects Agency (DARPA) was researching and developing a new anti-personnel gun.

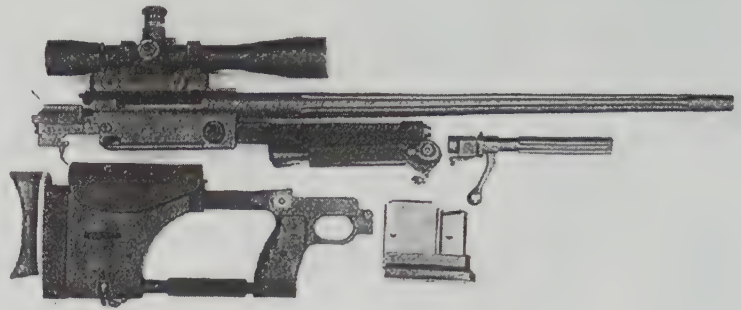
In 1969, DARPA modified a Boys anti-tank rifle to fire a flechette round. The barrel was a smooth bore and the rifle weighed about 35 pounds. The listed muzzle velocity was around 4,500 feet per second. The gun's only decent feature was a flat trajectory and the ability to penetrate armor at a closer range. At 600 yards, a typical shot group would be about 6 to 8 feet in diameter. Two guns were prototyped with another 16 being constructed. There is not much information available on the operational use of these rifles.

During the Vietnam War, the development of sniper rifles in general went in two different directions. The Marine Corps went the way of the bolt action rifle (smart move) and the Army went the way of the gas-operated rifle (not a smart move). There were no developments of heavy-class rifles with the exception of the PzB and the flechette rifles during this time. With the close of the Vietnam War, sniper weapons development across the board came to a halt. All the services were using the same systems into the early '80s that they had used in Vietnam. The Army had developed and was getting ready to field the M-24 Sniper Weapons System, arguably the finest 7.62mm sniper rifle in the world (sorry, Marines). Naval Special Operations was procuring their new M-86 7.62mm sniper rifle and the Marines were still using the fine M40A1.

The gap in heavy sniper rifle use and development stretches from the end of the Vietnam era to around early 1984. The original action or event that started the immediate demand within special operations to procure .50-caliber rifles is not factually known. One rumor that cannot be directly confirmed is that .50-caliber and 14.5mm rifles were procured for an effort to assist Afghan rebels in their war against the Soviet Union. The rifles were apparently needed to engage Soviet Hind helicopters on the ground. U.S.-made shoulder-fired anti-aircraft missiles were spirited into country for the flying threat. Somebody got the idea to use the big guns to try to shoot the helicopters on the ground. Not a bad idea, provided security doesn't push out 2,000 meters and there are sufficient avenues of escape.

A NEW KIND OF RIFLE

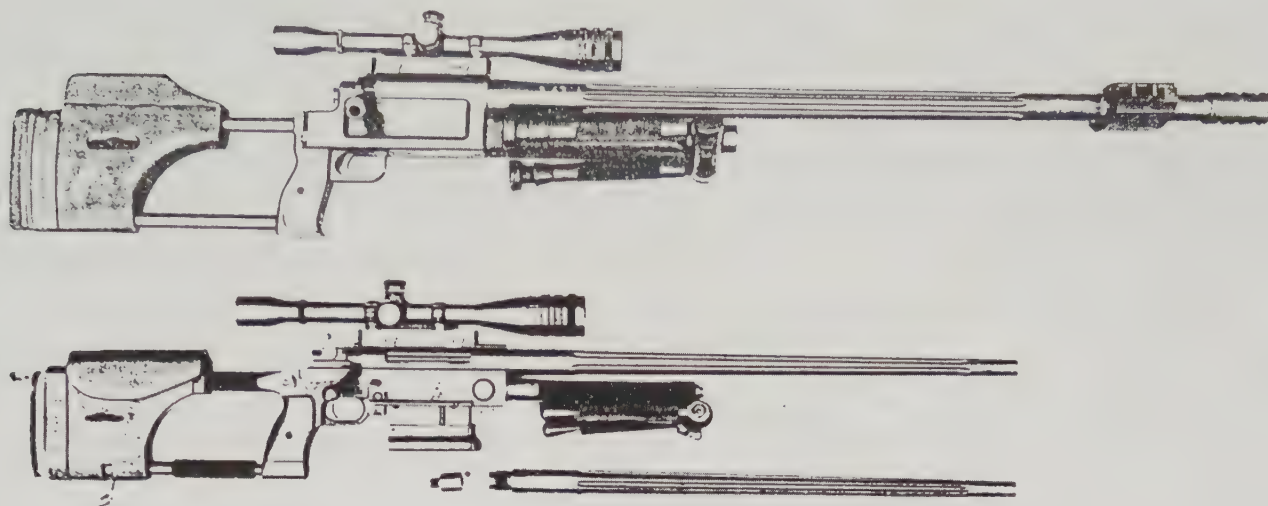
In the early '80s, an office with 1st Special Operations Command of the United States Army responded to a field request for an emergency purchase of a new kind of rifle. A company called Research Armament Industries, Inc. (RAI) developed the original rifles, actually creating two different rifle systems for the military. The first one, called the RAI Model 500 was the .50-caliber gun. This rifle was also referred to as the Special Application Sniper Rifle (SASR) or the Haskins Model 500 rifle. The other was the M300.



RAI M300 convertible 7.62mm x 51mm and .338/.416



RAI M500 .50 caliber.



Photos from the H.P. White tests of the RAI M500 and RAI M300 convertible rifles. The small part next to the spare barrel is the interchangeable bolt head for converting from 7.62mm to .338/.416. The optics on both guns is the Weaver T-16 target scope.

At the same time the U.S. Army Special Operations was procuring a .50-caliber rifle, the Naval Special Warfare people were issuing a Procurement Specification for a .50-caliber rifle. "The basic rifle was designed and manufactured by Research Armament Prototypes of Rogers, Arkansas. The SASR concept is under development by the U.S. Navy for the Navy Special Warfare and Army Special Operations Commands."¹ The terminology used in the procurement documents for both the Army and the Navy is the SASR. No specification can be found that was generated by the Army, but certainly one must have existed. The Marine Corps did not develop a specification sheet as the U.S. Navy was the lead on the project. This may be the reason that the Army did not produce a spec. sheet also. Here are some interesting extracts from the U.S. Navy specification document. These are selected items only and are not the entire document. Additional comments are added by the author.

Procurement Specification for Manufacture and Delivery of Special Application Sniper Rifles for the United States Navy

Paragraph 3.1.1 The rifle shall properly chamber and function any current .50-caliber service cartridge (M33 Ball, M17 tracer, M2 AP, M8 API, M20 APIT, Mark211, Mod-0 and .50-caliber Saboted Light Armor Penetrator (SLAP)).²

Paragraph 3.2.1 This rifle shall fire five consecutive 5-round groups at a distance of 600 yards. Three of the five groups shall have a mean radius³ of no greater than 5.0 inches or no greater than the mean radius given in the Naval Weapons Support Center (NAVWPNSUPPCEN) Crane ammunition assessment data for government furnished ammunition, whichever is greater.

Paragraph 3.3.3 The trigger pull of the weapon shall be in a range between 4.0 minimum and 6.0 maximum pound force.

Paragraph 3.3.4 The receiver shall have an integral rail/mount base which shall accept a quick detachable scope mount and rings.

Paragraph 3.4.1 The length of the barrel shall be 29 inches minimum to 32 inches maximum.

Paragraph 3.4.6 The barrel twist rate shall be approved in writing by NWSC, Crane.

Paragraph 3.5.1 The barrel shall have a detachable recoil reducing muzzle brake capable of reducing the

average peak recoil force and the average recoil impulse to equal to or less than the present .50-caliber Navy SASR with the original Haskins muzzle brake.

Paragraph 3.6.4 The rifle shall have an integral folding bipod capable of adjustment to give a muzzle height of 10.5 to 13.0 inches from a level surface.

Paragraph 3.7.1 The weapon shall have a Leupold & Stevens Ultra 16X-M1 or equivalent scope. The scope reticle shall be a 3/4 minute Mil Dot reticle. The scope shall have no less than 145 minutes of elevation (MOE). The scope shall be supplied with Leupold & Stevens rings and quick detachable mount or equivalent. The scope mount shall interface directly with the rifle receiver and maintain adjustment and position throughout the service life of the weapon.

Paragraph 3.7.2 The scope, scope rings, and mount shall be mounted on the rifle and aligned such that when the weapon is sighted in at 100 yards under minimal (0-10 mph) wind conditions there shall be available 22 minutes right windage, 22 minutes left windage, and 130 MOE remaining.⁴

Paragraph 4.9.3 All firing for accuracy shall be at a distance of 600 yards, +10, and -0.

If you look at this data and compare the specifications to the guns of the times and even most of the current ones, you see the items that set trends that still continue. RAI designed and prototyped the gun before this document was written. Certainly, these designs and developments were done with the Navy looking in on them along the way. RAI did a great job of setting up the original gun design that we still see now. The AMAC .50-caliber gun is almost identical to the original M500 guns of the time. The scope specification that set up the MOA for elevation remaining set up the 60 MOA base that is still used on virtually every bolt action .50-caliber gun in the industry. The only dissenters in this angle theory are the semi-automatic rifles, particularly the Barrett.

Paragraph 3.5.1 refers to the original Haskins design. (The RAI 500, the M500 Haskins and the SASR are all basically the same gun.) The Army and Navy already had some M500s as are seen on page 7 for testing and development purposes. The rifle that you see on page 6 is the result of the specification sheet from the U.S. Navy. The rifle with the T-16 scope was the design that was tested by H.P. White Laboratories and finalized in a report dated August 1985. Aberdeen Proving Grounds tested the version that more closely resembles the Navy specification sheet that is referenced above.

At the same time the Army and Navy were doing their procurement and development programs the Marines were taking an interest in the weapons. In February of 1984, a Marine liaison officer to the Joint Service Small Arms Program (JSSAP) went to the U.S.M.C. Marksmanship Training Unit to obtain information about the Navy's .50-caliber sniper rifle. On the January 20, 1984, the HQ U.S.M.C. tasked the Scout-Sniper Instructor to zero, LTI, and function check .50-caliber sniper rifles for employment by the 22nd MAU. They also instructed members of the 22nd MAU in the use of the guns. That's an interesting situation considering that no expertise even existed on the guns at that time. All training would have been completely off the cuff.

It is at this time the mentality developed that assumed any trained sniper could fire and employ a .50-caliber rifle. Chapter 4 deals more with the subject of light rifle-trained snipers using the heavy guns without specialized training. The training was completed on February 10, 1984. Some of the problems that occurred in that training were problems that plagued the M500 rifles for their entire service life. While this was not an official test of the weapon, operator-level feedback is usually more grounded in common sense than are the scientific evaluations of the weapons.

UNOFFICIAL U.S.M.C. TEST RESULTS OF TRAINING 22ND MAU

- On the average, all four weapons (all M500s) experienced failures to fire once in every eight rounds. It appeared that there were two causes for this problem. The reader must understand that these are the *apparent* problems, not the scientific results of testing and evaluation. First, the firing pin hole is not large enough. This didn't allow the firing pin to travel far enough forward to strike the primer on the cartridge. Second, the firing pin spring is cocked when the bolt is rotated to unlock. This keeps the firing pin spring

compressed for extended periods of time, and possibly weakens it to the point where it fails to provide enough force for the firing pin to adequately strike the primer.⁵

- After firing four or five consecutive rounds, the bolt “binds up” and is impossible to manually unlock or extract. Shooters have been forced to use rubber hammers to beat open the bolts on all four weapons.
- The bipod locking mechanism on all four weapons has exhibited excessive wear. As a result, the bipods are unstable and frequently collapse under the combination of weapon weight and shooters leaning into it.⁶
- During firing, brass filings have been noted in the chambers of all four weapons. It has become necessary to clean the filings out every 10 rounds.
- One weapon has twice prematurely fired before the bolt was completely locked down. This has not resulted in injury, but it is a safety consideration worthy of note.⁷
- There is no safety on the four weapons as fired. Once the bolt is locked into the receiver, there is no mechanism to render the weapon safe. Because the firing pin is cocked on unlocking, from the moment the projectile is inserted in the bolt (which is done outside the weapon) there is the possibility of accidental discharge.⁸
- Initially, continuous firing caused the Weaver scope to rotate in the scope rings. This problem was eliminated by simply milling the rings smaller and stippling the inside of the ring surfaces.⁹
- Factory specifications indicate that the Weaver T16 scope has a total of 60 MOE travel. Experience has shown that when firing the Norwegian Raufoss ammunition, a total of 85 MOE is needed to range from 300 to 1,500 yards. It is felt that the limited amount of elevation available on the Weaver T16 makes it inadequate.¹⁰
- Accuracy Level Recorded:
 300 yards – 1.5-2 MOA
 1,000 yards – 1.5 MOA
 1,300 yards – 1.5 MOA
 1,700 yards – 2 to 2.5 MOA¹¹
- Observations on the Problems from Overpressure: The synopsis of this paragraph is as follows:

“Ear plugs/sound suppressors must be worn. It is the opinion of those who fired the weapon that hearing protection must be worn even on tactical missions. Safety glasses also must be worn because of the blast debris from the muzzle brake. The team observer must be repositioned. U.S.M.C. sniper teams employ an observer (as does everybody else) alongside and slightly behind the shooter. Because the observer receives more of the blast than does the shooter, he must be repositioned.”¹²

Document Note: There is currently no employment doctrine published for the subject weapon. Operational use of the weapon and ammunition is solely at the direction of the commanding general (CG), 22nd MAU.¹³

The following is a chronological list of the procurement of the .50-caliber sniper rifle in the Marine Corps:

Date: Mid to late Dec 1983

Event: CG, FMFLANT (Fleet Marine Force Atlantic) sends a letter to CG, 22nd MAU outlining a “shopping list” of available non Table of Equipment weapons and ammunition. (These are items not on the authorized list, available on the civilian market.)

Date: Late Dec 1983

Event: CG, 22nd MAU responds to CG, FMFLANT requesting, among other things, the .50-caliber sniper rifle and ammunition to support it.

Date: Dec. 30, 1983

Event: CG, FMFLANT requests Commandant Marine Corps (CMC) to procure and forward to 22nd MAU the .50-caliber sniper rifle and Norwegian Raufoss .50-caliber ammunition.

Date: Jan. 19, 1984

Event: An Acquisition Decision Memorandum (ADM) gives CMC approval to CG, FMFLANT request.

Date: Jan. 20, 1984

Event: A point-of-contact meeting at Headquarters Marine Corps (HQMC) gathers information on weapon and ammunition procurement as well as training requirements. A CMC message directs the procurement of weapons and ammunition.

Date: Jan. 25, 1984

Event: U.S.M.C. procures ten .50-caliber Sniper Rifles at a cost of \$62,000.00.

JOINT MUNITIONS EFFECTIVENESS MANUAL

There is a classified manual in use within the U.S. Armed Forces called the Joint Munitions Effectiveness Manual (JMEM). Essentially, this manual is used to determine points of attack on specific selected targets by different weapons systems. For example, it may state that it takes a minimum of 10 rounds from a .30 caliber machine gun to damage a certain piece of equipment. The material is classified as it indicates points of aim on the outside of a specific item, a van for example. When the .50-caliber SASRs started hitting the various special operations units in 1984, a series of tests were set up by the United States Army DARCOM (Development and Research Command) Special Projects activity. The information presented here is a synopsis of this testing. All material here is gleaned from an unclassified information paper based on the test conducted in October 1984.

This was the first formally conducted test by operator level personnel rather than science laboratories. The test provides some very keen insight into the weapons capabilities of those days. It also shows some of the weak points of the earlier guns. Not all of the data in the test is published here. Only the major and significant observations are reported.

Synopsis of the Information Paper¹⁴ Long Range Special Application Sniper Rifle (JMEM) Test

- Three shooters from Naval Special Warfare were selected for the tests. Each shooter fired three 10-round groups at ranges of 200, 1,000, 1,500 and 2,000 yards. All rounds were fired from the prone position with the systems' attached bipod. The ammunition used in the test was the EX 211, Mod-0, a multi-purpose Norwegian cartridge later known as the Mark 211, Mod-0. But at this point the cartridge was not yet type classified for use in the United States.
- The table below summarizes the measured extreme spreads at each range. The data for all three shooters is included in the results:

Range	Extreme spread (10-round groups)		
	Smallest	Average	Largest
200 yards	5.2 inches	8.0 inches	12.0 inches
1,000 yards	26.8 inches	42.2 inches	66.1 inches
1,500 yards	64.8 inches	94.1 inches	121.9 inches
2,000 yards	147.0 inches	172.3 inches	201.1 inches

- This is a quote from Paragraph 7 of the information paper. "The results of the JMEM tests indicated that the prototype rifle and multipurpose ammunition as a system did not satisfy the current operational requirements. These were the first formal systems tests to provide this information. When terminal

performance, accuracy, and portability are considered jointly, however, this remains the most effective system of its kind in use within the U.S. Department of Defense.”

- Prior to the JMEM tests being conducted, NWSC, Crane, personnel suspected that the EX211, Mod-0 ammunition could not or was not manufactured to a high enough tolerance to meet the accuracy requirement at ranges past 1,500 yards. Crane conducted computer firing simulations that incorporated the following variables. The results are listed below.

1. Actual measured variations in the projectile mass (Component A).
2. Actual measured variations in the muzzle velocity from the rifles (Component B).
3. Practical estimates of shooter error based on in-house data (Component C).

Range	Extreme spread (10-round groups)		
	Smallest	Average	Largest
200 yards	3.1 inches	4.6 inches	5.2 inches
1,000 yards	19.4 inches	24.3 inches	28.7 inches
1,500 yards	40.7 inches	51.9 inches	67.9 inches
2,000 yards	60.6 inches	106.8 inches	162.9 inches

- At ranges out to 1,500 yards, the simulations can account for about 57 percent of the extreme spreads recorded in the JMEM tests. The simulations also showed that the maximum point-blank range for a target 79 inches in diameter at a zero range 2,000 yards is 2,021 yards due to the highly curved trajectory at this range. To strike a target that is 79 inches high at about 2,000 yards, you would have to know the range to the target with 1 percent of the range.¹⁵
- The computer simulations neglected the effects of the following items. These items, components D through G, account for the remaining 43 percent of the tests extreme spreads.

1. Time of flight, crosswind variations (Component D)
 2. Variations in the outer profile of the projectile or misalignment of the penetrator within the projectile (Component E)
 3. Scope movement (Component F)
 4. Rifle-induced launch yaw of the bullet, muzzle whip, blast effects, etc. (Component G)
- Component D, time of flight and crosswind variations is the deflection of the projectile due to random changes in the velocity and/or the direction of the crosswind while the projectile is in flight. This effect can only be reduced by fundamental changes to the projectile itself. This can be done by simultaneously reducing the diameter of the bullet, increasing its mass, and increasing its muzzle velocity.¹⁶
 - The effects of both constant and variable crosswinds can be predicted. The table below shows the deflections on the target at various ranges that would result from a constant crosswind of 2 mph and a variable crosswind that increases from 0 to 2 mph over the trajectory of the shot.

Range	Deflection (2 mph crosswind)	
	Constant	Variable

200 yards	0.4 inches	0.3 inches
600 yards	3.7 inches	2.5 inches
1,000 yards	10.9 inches	7.4 inches
1,500 yards	26.9 inches	18.5 inches
2,000 yards	52.6 inches	36.6 inches ^{17/18}

- Note that the deflections resulting from a 2-mph variable crosswind are only about 15 percent of the average measured extreme spreads at each range. If this were statistically extracted from the JMEM data at 2,000 yards, the extreme spread would decrease by less than 4 inches.
- Improvements to the RAI Long Range SASR could reduce the extreme spreads at intermediate ranges (200-1,500 yards) by 25 percent or more. To control launch bullet yaw, muzzle whip, blast effects, etc. ,it will be necessary to optimize the muzzle brake and flash-hider assembly.
- The firing simulations show that at the very long ranges of 1,500 yards and beyond, projectile mass difference (A) and muzzle velocity variations (B) contribute more to the extreme spread than the estimate shooter error (C).¹⁹

Range (yards)	Extreme Spread (inches)(10 round groups)		
	(A) + (B)	(C)	(A)+(B)+(C)
200	0.4	4.3	4.6
1,000	13.0	21.2	24.3
1,500	43.4	30.4	51.9
2,000	88.6	45.8	106.8

The figures in column (A)+(B) are the results of a simulation in which the estimated shooter error (C) is “turned off.” In column (C), the effects of varying projectile masses and muzzle velocities have been “turned off.” At ranges beyond about 1,250 yards, factors (A) and (B) predominate. At that range, the shooter begins to lose control of his round. This means that no matter how perfectly the shooter does his job, he can no longer affect the extreme spread minimums of the group of shots.

In order to utilize the talents of the shooter at ranges beyond 1,250 yards, it will be necessary to reduce the mass and muzzle velocity variations of the EX211, Mod-0 cartridge.

Conclusion

- This system does not yet meet the current operational requirements.²⁰
- Testing for the JMEM publication in 1984 shows that the system consisting of the SASR and the EX211, Mod-0 cartridge has advanced the state of the art in long-range sniping.
- At ranges less than 1,250 yards, design improvements to the rifle alone could decrease extreme spreads for 10-round groups by 25 percent or more.
- At ranges beyond 1,250 yards, improvements to both the rifle and the ammunition are needed before the accuracy of the system is limited by shooter error and environmental conditions. Improvements to the cartridge—which will reduce projectile dimensional and mass variations—as well as improvements to both the ammunition and the rifle to reduce the muzzle velocity variations are needed.²¹
- The suitability of any system that uses conventional .50-caliber ammunition for sniping at ranges near 2,000 yards is questionable. The attainability of the required rifle and cartridge tolerance in a production

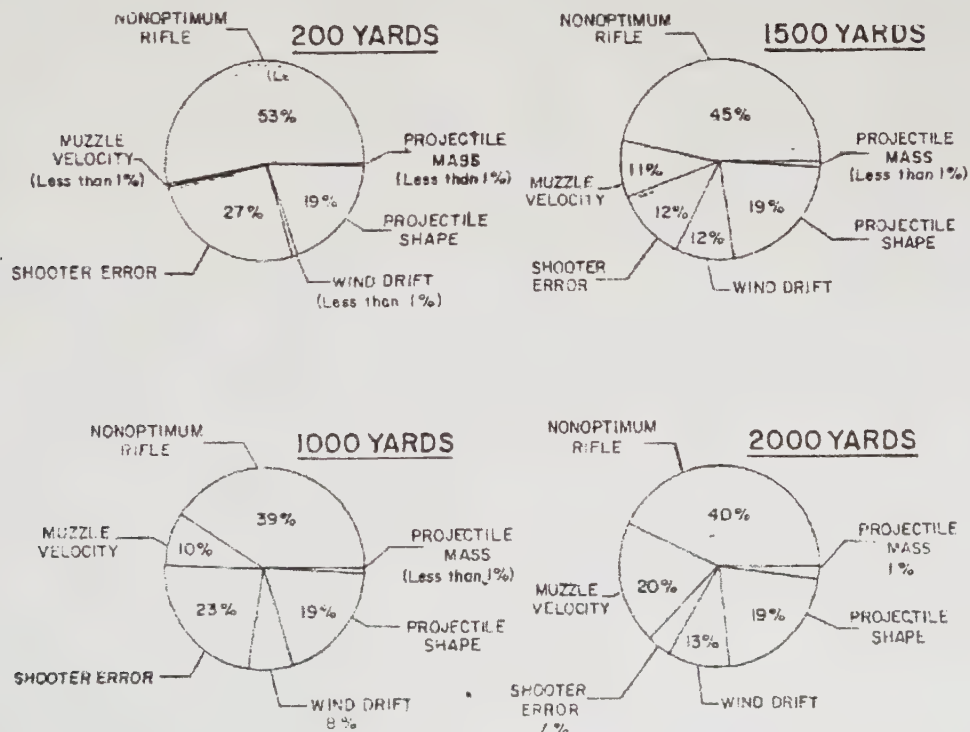
environment as well as their maintenance thereafter has not yet been demonstrated. Range determinations must be accurate to within 1 percent.

SYNOPSIS OF THE ABERDEEN PROVING GROUNDS TEST

There was another test conducted by Aberdeen Proving Grounds that centered mostly in accuracy capabilities. This test is dated March, 1985. Here are some of the facts that are presented in the test.

- The telescopic sight used was the Leupold & Stevens 16X Ultra, M-1
- The results of the accuracy tests are a combination of EX211, Mod-0 and M-33 Ball ammunition.²²
- The test was done with four separate rifles.
- The guns were tested at 200, 1,000, 1,500, and 2,000 yards.
- U.S. Navy Special Warfare personnel were used as the gunners in this test also.
- There was no interchange of operators and weapons during the conduct of the test.
- The Single Shot Hit Probability (SSHP) is based on a target that is 1.8 meters or 6 feet square.

Range in Yards	# Rounds Fired	Average Extreme Spread (MOA)	Average Single Shot Hit Probability
200	86	3.99	1.00
1000	90	3.98	.9733
1500	90	5.62	.6600
2000	90	8.60	.2933



As you can see in the extreme spread in MOA column, the results were not encouraging. Remember that the two different types of ammunition are combined for these numbers. It is likely that the M-33 Ball is responsible for more than 60 percent of the large figures in these ranges. Not until 1994 did M-33 Ball get accurate enough to be considered for use, even as a training cartridge.

Something that must be noted while comparing the methods of testing and the results of the tests is that none of the tests are conducted with any similarity. Different units of measure for accuracy are used. Some weapons are shoulder-fired and some are fixture-fired. In the case of the Aberdeen test, the best and worst ammunition available at the time was lumped together to provide accuracy data. That may have been no test at all. At a minimum, the two types of ammunition should be printed separately.

The final test that we will take a look at is a test conducted by H.P. White Laboratories. The lab is an independent testing facility that frequently develops test data for government and private projects.

SYNOPSIS OF THE H.P. WHITE LABORATORY TEST

In support of special military operations, Research Armament Industries, Inc. (RAI) developed three long-range, bolt-action rifles intended to minimize dispersion and optimize the probability of first-round hits. To date, dispersion testing of each of the three rifles has been limited to shoulder-fired testing. Four prototype rifles (new condition) of each type (caliber) were provided by Logistics Management Engineering, Inc. for these tests.²³

The prototype rifles submitted for testing were of two basic types —.50-caliber (4 each) and 7.62 x 51mm (4 each), the latter of which were convertible to 8.58mm using alternate barrels, bolt heads, and magazines provided with the basic rifles. All were bolt-action rifles produced by RAI with bipods and telescopic sights. The .50-caliber, M33 Ball ammunition and 7.62mm, M852 Match ammunition used in these tests were U.S. military loadings. The .50-caliber, EX211, Mod-0 API ammunition and 8.58mm ammunition were loaded by the A/S Raufoss Ammunition Company (Norway) and RAI, respectively. The 8.58mm ammunition was apparently a “wildcat” loading of .416-caliber Rigby case necked-down to accommodate a .338-caliber, 250-grain JHP bullet. These are the test facts as presented in the test document:

- The telescopic sight used on all weapons was the Weaver T16.
- The ammunition used was the M33 Ball and EX211, Mod-0 Raufoss.
- The comparison accuracy data was obtained by firing the M500 from the shoulder, from a test fixture and data obtained from a MANN precision test barrel.
- The range for the M500 testing was done at 100 and 200 yards.

The table below is a summary of the muzzle velocity of the cartridges when fired through the MANN test barrel. All three weapons are included in the results of this test, since this was a systems evaluation. Note the extreme spread of the muzzle velocity of the M33 Ball cartridge. This 87-feet per second (fps) spread accounts for a huge amount of dispersion at all ranges. The EX211, Mod-0 round actually did worse with an extreme spread for velocity of 176 fps. Note the dispersion in the far right column as a result of this velocity spread. Not all of that dispersion is from the spread, but it's a huge piece of it. The M-852 and the 8.58mm cartridge have an extreme spread for velocity of 50 fps and 53 fps respectively.

This table is a result of tests conducted on an indoor range while the rifles were put into a firing fixture. The use of a fixture does not mean that the results are a condemnation of the system. Frequently fixtures, unless they are perfectly set up and designed for a particular system, cause more problems than they cure. Vibration from a rigidly fixed system usually causes more dispersion than does a shoulder fired gun. In fact, on page 12 of the H.P. White report, the technicians themselves identify a problem with the fixture assembly.

“The data of Table V indicates the gun-attributable dispersion is significant (compare MANN and Fixture

firings), however, that data may be misleading. While some increase in Fixture firings of the rifles over the dispersion of MANN barrel firings is to be expected, the extent of the increase demonstrated by the table is, in our judgement, excessive and attributable to the fixturing. The fixturing of the rifles clamped the forend mounting rod and the buttstock. Some movement of the barrel of the fixtured rifles was noted. The movement was detectable in each rifle of all calibers but varied from rifle to rifle and was attributable to the quick disconnect feature of the buttstock.⁷²⁴ Here are some observations that are made independent of the test observations:

- The average deviation in muzzle velocities for all four .50-caliber guns was 111.25 fps.
- When shooting M33 Ball, the gun (#500007) with the most velocity deviation had the least amount of shot dispersion.
- The gun (#500008) with the least velocity dispersion had the greatest shot to shot dispersion.

VELOCITIES AND DISPERSION FROM MANN TEST BARREL AT 100 YARDS										
Cartridge	Rounds Fired	Bullet Velocity(fps)			Peak Press.(CUPx1000)			Groups	Dispersion(in)	
		Max.	Min.	Avg.	Max.	Min.	Avg.		Max.	Min.
.50,M33	9	2852	2765	2824	47.0	42.5	45.6	3	2.25	1.00
.50,EX211	9	2902	2726	2864	51.0	39.8	48.4	3	3.75	1.85
7.62mm,M852	9	2594	2544	2574	56.0	51.4	54.2	3	1.60	0.70
8.58mm	9	2864	2811	2836	56.8	52.5	54.9	3	2.55	0.75

INDOOR TEST FROM FIRING FIXTURE AT 100 YARDS							
Rifle	Serial Number	Ammunition	Groups	Velocity(fps)		Dispersion(in)	
				Maximum	Minimum	Maximum	Minimum
<u>Caliber .50</u>							
	500005	M33, Ball	3	2705	2610	12.25	4.65
	500007	M33, Ball	3	2714	2543	4.40	2.25
	500008	M33, Ball	3	2674	2620	12.70	2.85
	500019	M33, Ball	3	2741	2616	4.90	3.00
	500005(a)	M33, Ball	3	2722	2617	14.45	7.30
	500008(a)	M33, Ball	3	2720	2543	4.85	2.90
<u>8.58mm (Convertible)</u>							
	010	8.58, Ball	3	2854	2779	4.20	2.80
	018	8.58, Ball	3	2930	2827	6.65	2.15
	A3052D	8.58, Ball	3	2838	2761	2.80	1.35
	A3055D	8.58, Ball	3	2878	2807	7.40	2.40
<u>7.62mm (Convertible)</u>							
	010	7.62,M852	3	2658	2590	2.50	0.80
	018	7.62,M852	3	2656	2609	3.10	1.10
	A3052D	7.62,M852	3	2622	2572	1.10	0.65
	A3055D	7.62,M852	3	2649	2575	1.95	0.95
(a) Fired without muzzle attachment.							

- Gun #500008 had a shot dispersion of 12.70 maximum and 2.85 minimum with the muzzle brake installed, yet without a muzzle brake, the dispersion was 4.80 maximum and 2.90 minimum.
- The test on the 8.58mm gun yielded the same anomaly, but on a lesser scale.

It is interesting to note the above anomalies. They make no sense. A gun with the greatest spread in velocity deviation should not have the least shot-to-shot dispersion. It is quite possible that two things occurred, maybe simultaneously: The fixture is flawed and allowed movement in the gun system and the clamping action caused a vibration problem within the gun. Since the groups appear at random, this lends the bad fixture problem greater weight than does the vibration argument.

The accuracy results of this test also greatly contrast with the informal test that the U.S.M.C. conducted with virtually the same rifle. The data above suggests an accuracy level of anywhere from 2.25 MOA to 12.70 MOA with a muzzle brake in place. The U.S.M.C. test states that they achieved 2 to 2.5 minutes of angle at ranges out to 1,700 yards. At the short range of 300 yards, the human-fired guns achieved 1.5 to 2 minutes of angle. Remember that the bullet is very much subsonic at the range of 1,700 yards (unless the MET and ENV conditions favored otherwise). Yet they still achieved higher accuracy fired from a human shoulder at 1,700 yards than did the fixture-fired guns at 100 yards. Personally, I believe the U.S.M.C. test without a doubt. I also believe the scientists at H.P. White when they said the fixture was creating a problem. It did, without a doubt. Now if you think the above data is funny, check out the next table.

The table below is a summary of the outdoors 200-yard test that was conducted. The rifle was again set into a firing fixture. The ammunition in the test was both the EX211, Mod-0 and the M-33 Ball cartridges. No velocities were given on this summary of the test. Some very interesting bits of data show though on this test too. Comparing the data gun by gun against the indoor 100-yard test revealed the following information. The data from the table is in inches and has been converted to MOA for the summary below:

- Gun #500005 had an average dispersion at 100 yards of 8.45 MOA. Gun # 500005 suddenly shot better at 200 yards with a dispersion of 5.27 MOA. This average dispersion is 60.19 percent better than at 100 yards. (M-33 Ball).
- Gun #500007 had an average dispersion at 100 yards of 3.33 MOA. At 200 yards, Gun # 500007 had an average dispersion of 5.53 MOA. This is a loss in accuracy of 66.31 percent over the 100-yard figure. (M-33 Ball).
- Gun #500008 had an average dispersion of 7.70 MOA at 100 yards. Note from the table the high and low dispersion of this gun in this test. There are extreme differences between the two figures. At 200 yards the gun suddenly got more consistent in its groups. The 200-yard average dispersion is only 3.38 MOA. This is a gain of 127 percent from the 100-yard figure. (M-33 Ball).
- Gun #500019 had an average spread of 3.95 MOA at 100 yards. This gun had the worst loss of accuracy when shifted to the outside 200-yard test. The gun's average dispersion at 200 yards was 7.72 MOA. This is a loss of 95.56 percent from the 100-yard test. (M-33 Ball).

The data is starting to show probable flaws in the testing while using the firing fixture. Guns just do not have these radical shifts in their group size. Even more disturbing are the huge gains in accuracy at 200 yards versus 100 yards. Gun #500008 had a huge gain in accuracy at the 200-yard line. Now we will break down the data for the different rifles shooting the EX211, Mod-0 cartridge. This cartridge is more accurate across the board than the M-33 Ball of the time. Unfortunately, no velocity data is offered:

- Gun #500005 had an average 200-yard dispersion with EX211, Mod-0 ammo of 5.27 MOA. This is a loss in accuracy of 92.70 percent over the M-33 Ball at this range.
- Gun #500007 had an average 200-yard dispersion with EX211 ammo of 3.06 MOA. This is a gain in accuracy of 80.81 percent over the M-33 Ball.

- Gun #500008, according to the data, had precisely the same extreme spread average (the same high and low also) with both M-33 Ball and EX211, Mod-0 cartridges. While this is not impossible, the odds of this actually happening are astronomically high. The written data is suspect in this case.
- Gun #500019 was the only weapon to exhibit a change in the group size that is somewhat consistent with what you might expect between the EX211, Mod-0 and the M-33 Ball cartridge. While both average extreme spreads were large. The average for M-33 Ball was 7.72 MOA and with the EX211, Mod-0 round, the average spread was 3.25 MOA. This is a gain of 137.69 percent over the M-33 Ball round. Even with this promising data, there is a huge difference between the smallest group size (1.13 MOA vs. 5.37 MOA with the EX211 Mod-0 cartridge).

The technicians at H.P. White Laboratories offered the following observations while the testing was conducted.

1. The light transmission through the telescopic sight (Weaver T16) was inadequate and created a “foggy” image at 100 yards.
2. The elevation control of the telescopic sight was insufficient. The sight had to be shimmed to bring the line-of-sight and line-of-fire into coincidence at 100 yards.
3. The cheek rest was too high and too far to the rear and could not be adjusted to a comfortable position, which made sighting difficult.²⁵
4. The magazine repeatedly dismounted from recoil (8.58mm and 7.62mm).
5. The safety had no positive detent or other indication of the safe and fire positions. The shooter frequently was unable to fire because the safety was not fully in the fire position.
6. Evaluation of the telescopic sight of these rifles was beyond the scope of these tests. However, in the opinion of H.P. White Laboratory, the reduced light transmission of the scope will very likely have an undesirable effect on shoulder fired dispersion at extended ranges.
7. White’s Executive Summary of the Test. The results of these tests demonstrate that the average dispersion of the fixtured rifle firings varies from 10.6 to 5.4 MOA, which is slightly better than shoulder firings conducted previously²⁶ and 2 to 5 times greater than the MANN barrel firings of the same ammunition. However, the fixturing process is known to contribute to the dispersion of these tests, but the level of that contribution is indeterminable without further testing.

A NEED FOR TRAINING

This fast purchase of the RAI M500 rifles in the early ’80s was by far the most involved upgrade of the sniper capability of the special operations forces for the United States. This procurement and testing process went on throughout 1983 to 1985. Different numbers of guns went to different places. As a veteran of the 1st Special Forces Group at Fort Lewis, Washington, I know that we had two of the RAI M500s. Both of those guns were equipped with the 16X Leupold & Stevens Ultra M-1 scope. When they were correctly tuned, both guns shot quite well. The weapons pool at the United States Army John F. Kennedy Special Warfare Center and School (USAJFKSWCS) had 2 of the M500s with Weaver T16 scopes on them.

The Navy Special Warfare people eventually decided to procure another type of .50-caliber rifle and picked up the M-88 takedown rifle from Gale McMillan of McMillan Gunworks. The Army made no further procurement attempts for .50-caliber rifles. Many of the guns that went to the special forces groups were not repaired, and they had problems or failed. The Navy sent SEALs to the SOTIC course at Fort Bragg, N.C., in 1988, when the author was instructing there. The SEALs attended these in addition to the schools that the Navy Special Warfare Groups were running on the east and west coasts.

The Navy operators always brought their .50-caliber rifles with them. They had incorrectly figured that

THE COMPLETE .50-CALIBER SNIPER COURSE

SUMMARY OF OUTDOOR TESTS FIRED AT 200 YARDS					
Rifle Serial Number	Ammunition	Groups	Range (yards)	Dispersion (in)	
				Maximum	Minimum
Caliber .50					
500005	M33, Ball	3	200	7.10	3.85
500007	M33, Ball	3	200	12.50	9.65
500008	M33, Ball	3	200	7.35	5.20
500019	M33, Ball	3	200	18.90	12.00
500005	EX211,MOD O,API 3		200	14.50	6.60
500007	EX211,MOD O,API 3		200	7.50	4.75
500008	EX211,MOD O,API 3		200	7.35	6.20
500019	EX211,MOD O,API 3		200	10.75	2.25
8.58mm (Convertible)					
010	8.58, Ball	3	400	7.00	2.90
018	8.58, Ball	3	400	12.05	7.75
A3052D	8.58, Ball	3	400	7.75	6.05
A3055D	8.58, Ball	3	400	8.95	2.30

there would be training conducted on the heavy rifles. They got this opinion because in the Special Warfare course catalog, it was mentioned that training on the .50-caliber was conducted as part of the SOTIC course. In reality, this training consisted of shooting the committees "borrowed" M600 Daisy rifle. They did this for 10 rounds per student at the 1,000-yard line.²⁷ That was the sum of the training on the heavy rifles. As the author developed data and techniques for the employment of the heavy guns, the SEAL snipers and anyone else who wanted to attend on their own time were offered weekend seminars when everyone else was off. The Navy guys always showed up, to a man. Rarely did anyone else attend the training. Those who did were from the Ranger Battalion or the 82nd Airborne Division. The Army Special Forces operators may have been reflecting their command's concern about snipers and sniper training, although it was more likely a matter of being very tired.

Paperwork

It was after three of these courses were run that it was decided to present a concept to the chain of command that would either include more time for HTI training in the SOTIC course or add a totally new course. A memorandum dated Sept. 4, 1989, was forwarded to the commander of 2nd Battalion, (SOTIC was a unit within this command) requesting authority to present a training concept to the commander of the 1st Special Warfare Training Group (SWTG), the major training unit that runs the Special Forces Qualification Course and all the advanced skills schools for special operations forces of all the services. While waiting for approval to brief the commander on a training concept, we were given approval to brief the Directorate of Combat Developments (DCD). DCD is the entity responsible for researching and being part of the procurement of new systems for use within Army Special Operations. They stay on the cutting edge of new weapons, parachutes, scopes, and literally anything that may be of use to special operations. Their reception was open and very positive. The problem wasn't in the material developments branch. It came from within our own chain of command. As SOTIC saw it, the weapons were already in the units in the form of the RAI M500 rifles. No one was running any training program on the weapon or the operational use of the weapon.



McMillan Gunworks M-88 as procured by Naval Special Warfare in the late 1980s.

As we saw it, we were responsible to train SOF snipers in all sniper weapons systems within the inventory. The chain of command didn't see it that way.

In a document from Col. John Moroney, Commander, 1st SWTG, dated Dec. 4, 1989, the response was anything but positive. The commander misunderstood a request for a training package be added to the SOTIC program as a request for weapons. To be honest we were a bit shocked at the outcome of this request. We knew that funding would be a problem, as well as deciding what time of the year to do the course. (SOTIC runs classes from February to November only. During the winter season, there is no course because of the foul weather and the subsequent effect on the student's ability to learn the craft.) One paragraph was particularly baffling. It was written as if there were no system like the .50 in SOF. There were clearly systems in SOF. It was in 1989 when the U.S. Navy began procuring their second heavy rifle, the McMillan M-88. The Navy was not ignoring the problem however, and they began running their own courses. They were thinking dynamically, while the USAJFKSWCS, responsible for all the training of multi-service special operations forces, was ignoring the shortfall. Not only was the request refused, no further correspondence was to be sent up on the subject again. The Special Warfare Center is known for its excellent training programs worldwide. It seemed that anything that came "up from the bottom," so to speak, was totally unacceptable. One officer, who is now a lieutenant colonel and slotted to be an SF group commander, said after reading the concept, "This thing is so dynamic that it will have to be front-doored by a field grade officer to be accepted." This loosely means than nothing so dynamic could come from the enlisted men at the sniper committee. It would only have a chance if an officer pushed it through. In a few years at the 1st SFGA, this would prove true. In December 1989, the subject of HTI was officially banned at the SOTIC committee, the entity responsible for training SOF snipers in the weapons of their trade. Not until 1996 at 1st SFGA would an HTI course actually be set up and run. Through the next few months, the data tables were developed by the author and refined and test-fired with weapons that were borrowed and used from other units.

Saddam's Contribution

The next major event that brought attention to the subject of HTI was the invasion of Kuwait in August 1990 by Saddam Hussein's Iraqi Army. HTI had been set up to execute pre-emptive strikes against weapons of mass destruction (among other things), more specifically ballistic missiles. While the rest of the U.S. military machine was on alert and hopping out of Fort Bragg at a maddening rate, SOTIC prepared a document that



The Daisy M600 rifle that was "on loan" to SOTIC.

was an estimate of a training situation for Desert Shield special operations snipers. We knew that the training programs in the SF groups were weak for many reasons, their operational tempo being the major one. We suggested that the SOTIC committee be flown to the theatre to set in theatre training programs for SOF snipers. The U.S.M.C. sniper program was already doing the same thing. The concept and the estimate were drawn up and submitted to the chain of command.

Training the Trainers

In the meantime, the SOTIC committee began an intensive training program to bring instructor standards up even higher than they were already. The training was tailored to desert operations and the possible extreme effects on the men and equipment in the desert theatre. Within the 1st SWTG, commanders at every level were approving the deployment concept. In further preparation for an upcoming deployment the SOTIC committee split itself in half. Four individuals went to Remington at Ilion, New York, to work in their custom shop for a few days on M-24 Sniper Weapons Systems. They were there to get Remington Armorer-certified to work on the M-24 and become the first people in the armed forces to be trained in armorer maintenance on the rifle. Normally, the maintenance is operator level, and for anything other than that the gun goes to Remington. The other half of the committee went to Barrett Manufacturing in Murfreesboro, Tennessee.

The reader may wonder why we went to the Barrett Manufacturing plant. After all, the Army's heavy rifle was the RAI M500 and the Navy's were the M500 and the McMillan M-88. By this time, some AMAC 500s were in service with the Navy. The reason is that the United States Army Special Operations Command (USSOCOM), in response to an emergency request for purchase, was going to buy a bunch of Barrett M82A1 rifles for SOF forces in Saudi Arabia in support of operations. Additional rifles that were purchased for SOF included, M-25s, custom made .300 Winchester Magnum rifles, H&S Precision Takedown Guns, and some non-standard optical sights for these systems. Their response was excellent and fast. See page 21 for some of the systems that were brought to the theatre.

Complications

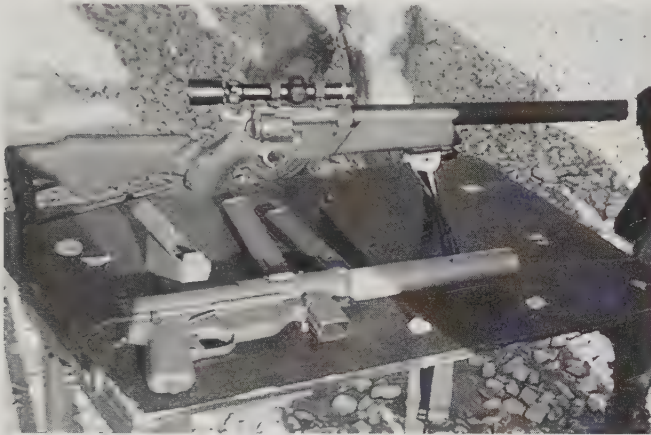
During this time, the author received several phone calls from operators that had been trained on some of these two-day weekend events during the SOTIC course. These calls were from various Naval Special Warfare people as well as colleagues in the Army SF unit in country. One of the problems that we were told was going to occur with us going into the theatre was that no unit had officially requested that SOTIC provide a Mobile Training Team (MTT) to train up snipers. The word was passed to these individuals that called that they needed to request the assistance through their chain of command. A funny thing happens sometimes when operators request assistance from someone outside of their unit. In the case of 5th SFGA requesting an MTT,



The M-25 system.



The M82A1 system.



Knights Armament .44-Magnum Ruger.



A 5th SFGA sniper with the M82A1.

an operations officer in the Group's S-3 (Operations) section stated that the 5th Group needed no assistance from anyone else. This was relayed to the author sometime after Desert Storm was over.

In the meantime, the CG of USAJFKSWCS had tentatively approved the committee's deployment, pending approval of an element called the Directorate of Training and Doctrine (DOTD). DOTD is an element within the USAJFKSWCS that is responsible for training standardization and doctrine for special operations. The word "doctrine" is a somewhat funny application within special operations. By the very nature of special operations, doctrine is something that is only a guideline, not something written in stone. However, in the last few years, doctrine has been a driving force not to be altered or questioned. Indeed, the term "doctrine nazi" was coined at the Joint Readiness Training Center at Fort Polk, Louisiana, where special operations units went for an annual training event similar to the major training center at Fort Irwin, California. Certain SF individuals that were supposed to be dynamic in thought became hardline followers of the "written word." If it wasn't written down somewhere, you didn't do it.

At some point, the pile of deployment papers, concept papers, and requests for deployment orders—about an inch thick in all—arrived at the office of the director of DOTD. This officer was not an SF qualified officer, but a non-airborne qualified military police officer (full colonel). According to a well-placed and well-connected source in that office, the previously mentioned officer asked this source one question: "Do we have a request for this from the theatre?" The source said truthfully that he did not. It never has been ascertained

what happened to the several requests that operators had sent up the chain of command in the desert theatre. With that word, the colonel of military police dumped the entire pile into the trashcan. To truly understand this mentality, you would have to have been at the USAJFKSWCS center at this time. The amount of professional jealousy was incredible. An officer assigned to the training group was overheard saying that the sniper committee only wanted to get in country to get combat patches.

No Response

Desert Shield/Storm passed without the SOTIC committee going anywhere, but the committee had its most intense training cycle ever. Instructors were shooting over 100 rounds per day with the M-24s. This went on for weeks, until it was time to start the first course of the season in February 1991. In a final attempt to generate some interest at the command level in the lack of training, a document was sent forward. This document concerned the influx of the new weapons into the SOF inventory because of Desert Shield/Storm. There were new .50-caliber rifles (about 88 each, M82A1s), any number of .300 Winchester Magnums, several M-25s and a few odds and ends. This document outlined a need for some of the weapons to be transferred to SOTIC so that they could be incorporated into the course. There was never any response from the chain of command concerning anything new until the author left the committee in 1991. As of October 1992, the SOTIC detachment at Fort Bragg did not receive any new or used .50-caliber rifles. They eventually did receive some of these and some SR-25s. To this day, there is still no formal training program for the .50-caliber sniper rifle.

On the heavy rifle timeline, the development and fielding of the Navy's M-88 rifle occurred in 1989. In a test conducted by NSWC, Crane in 1995, it was stated that the M-88 was nearing the end of its service life. The Navy decided to conduct a test of the Barrett M82A1 semi-automatic rifle. This gun was purchased on an emergency basis for the Desert Shield/Storm operation. When it was all over, there were guns scattered between the Army and the Marine Corps, with a very few in the Navy and Air Force inventories. No testing had been done yet.

The actual reason for the procurement of the M82A1 is difficult to put a finger on. USSOCOM's decision on what gun to buy happened so fast that no testing could possibly have taken place. The M82A1 was the rave gun of the time—it was very popular, but not very accurate. This was mostly due to ammunition problems, as most everybody was stuck with M-33 Ball. Only the Navy Special Warfare people were using what was now type-classified as Mark 211, Mod-0 ammunition (formerly EX211, Mod-0). Two paragraphs in this test indicate the use of the weapon for the Navy and problems related to the M-88 rifle:

EXTRACTS FROM THE NSWC, CRANE TEST ON BARRETT RIFLE

- **Paragraph 2.1** USSOCOM presently requires a Sniper Weapon System that will meet the Joint Operational Requirements Document for Heavy Sniper Rifle (HSR) as adopted March 16, 1994. The present SASR has significant shortcomings in meeting the HSR portion of the Family of Sniper Weapons Systems (FSWS). The FSWS will function in all types of assigned Special Operations Forces missions including unconventional warfare, special reconnaissance, direct action, counterterrorism and counternarcotic operations. The HSR element of the FSWS will provide long range degradation of designated materiel targets using target specific ammunition.
- **Paragraph 2.2** NAVSPECWARCOM (Navy Special Warfare Command) is also presently searching for a .50-caliber sniper rifle to replace the present SASR. The M-88, .50-caliber SASR produced by G. McMillan & Co., Inc. has developed safety concerns since it was fielded in 1989. The safety is known to release the sear and fire the weapon when operated from *safe* to *fire*. This led NSWC, Crane to remove all safeties from the M88 rifles.
- **Paragraph 2.3** The M88 is designed to be loaded by removing the cocked bolt, placing a live round on the bolt face, and replacing it in the receiver. This exposed round placed in front of a cocked firing pin has

always been a safety concern of the users and finally resulted in an explosive mishap at NSWC, Crane on July 21, 1994. It is also not uncommon for the bolt of the M88 to be extremely difficult to open after firing.²⁸

The details of this test are not further covered in this chapter. NSWC, Crane did however, make the human shooter a large part of the test and evaluation. (A detailed analysis of this test is examined in Chapter 4, "Introduction to the Training Environment.") The test does show that the some operators can shoot as good, or better than a good fixture designed to make a gun show its maximum performance capability. The fixture used by Crane was certainly better than the fixture used in the H.P. White tests. Here are the short results of the shoulder-fired versus fixture-fired tests:

- **Paragraph 5.4.2** The overall shoulder fired accuracy of the five weapons tested is 4.24 MOA. The overall shoulder fired accuracy when using the M8 API ammunition is 4.44 MOA and for the Mark 211, Mod-0, the accuracy is 3.77 MOA.
- **Paragraph 5.7.2** The 30 fixture fired accuracy tests averaged 4.70 MOA. The accuracy when shooting M8 API averaged 4.96 MOA and with the Mark 211, Mod-0, the accuracy was 4.44 MOA.
- **Paragraph 6.2.1.4** The Barrett did not meet the shoulder fired accuracy requirement of 2.00 MOA and did not shoot better than the test barrels used for lot acceptance.²⁹

SOTIC AT SFGA

In 1995, at the same time the testing was being done at Crane on the M82A1 rifle, a concept was being presented to the Commander, 1st SFGA at Fort Lewis, Washington. The SFGA commander then was Colonel Howard. The concept was to develop a full time sniper detachment at the group level. Their function was to ensure that 1st Group's snipers stayed proficient by providing them with the training, time, and resources to conduct hassle-free training. They also proposed to run Level II sniper courses and a Level I sniper course in a year's time.

After some thought, Howard approved the concept and on Oct. 1, 1995, the SOTIC detachment at 1st SFGA became reality. The detachment consisted of three personnel. The officer in charge was Major Gene Econ, known affectionately by his troops as "beercan." Among the operators, Major Econ was the most respected officer in the 1st Group. To many officers he was considered a pain in the butt. The reason is that Econ believed every soldier's job was to "close with and destroy the enemy." While he was the commander of A Company, 3rd Battalion, 1st SFGA, everyone in the company knew what their mission in life was: train for war. Not before that time and not since, has the team's mission been clearer. Many times, battalion commanders struggled with the definition of terms like close quarters combat (CQB), and questions such as, do CQB teams really need to exist? Do we really need 3 freefall teams within a battalion? Prepare for war? No time for that. By the way, Korea is one of 1st SFGA's countries of responsibility in the event of war. However, ask the average operator and he'd swear the command didn't know it existed. At 1st SFGA, preparation for combat just didn't seem a priority.

Staff Sergeant Bruce Bevans and the author, Sergeant First Class Dean Michaelis, were the other snipers assigned to the staff. The training staff ran two Level II courses in 1996. The first was three weeks long and the second was six weeks. During the six-week course, the students were given a two-day training period on the .50-caliber Barrett M82A1. The 1st SFGA was not assigned these weapons. They were obtained from an entity known as the Joint Operational Stocks warehouse (JOS). JOS is a sort of library of special equipment for all special operations forces from all the services. We also requested and received SR-25 7.62mm light rifles with suppressors and Navy-built (by NSWC, Crane) M-91 .300 Winchester Magnum rifles. The M82A1s came with Swarovski 10X scopes with the Barrett reticle pattern. We converted about half of the rifles we received. The Swarovski scopes were removed and we swapped them with 10X Leupold & Stevens Mark IV, M-1 scopes off the M-91 rifles.

The “Christmas tree” reticle pattern is only tuned for M-33 Ball ammunition and is a very sloppy way of shooting long distance. You will read in Chapter 5, “Sight Adjustment and Zero,” the reasons why the swap was made. There are only two ranges at Washington’s Fort Lewis where we could fire the .50-caliber rifle. They are Range 52 and Range 72. The students received a day in the classroom on the weapon, the ballistics tables, and the math involved and a day on the range with the rifles. While this was a beginning and sparked a tremendous interest in the program, it was insufficient training. The students did, however, learn how to make the guns shoot.

There have always been many comments about the accuracy of the Barrett rifle. Indeed, the 2nd Ranger Battalion was getting ready to send their rifles back because they couldn’t hit an “E” silhouette at 600 yards with the gun. Once the operators were trained as outlined in Chapter 8, “Training the Hard-Target Interdiction Operator,” the shooters were able to hit “E” silhouettes easily with the ammunition used that day. We had let snipers from the 2nd Ranger Battalion into the course for lots of good reasons. They were always attending the sustainment training we were running in between courses, and they always made excellent students for sniping. As a part of the deal to allow them into the course, they brought along with them some M-8 API ammunition. The 1st SFGA had only M-33 Ball and M-17 Tracer in their inventory. While we had the .50-caliber guns, we never had the ammunition for them. The M-8 API ammunition was World War II vintage with corrosive primers. (We didn’t know that at the time, and it was only learned after the author’s retirement during research on this book.)³⁰ The M-8 shot very well and the snipers were to obtain an accuracy level on an average of 1.5 MOA to a range of 700 yards. The photos on page 25 are of the training during the Level II course on range 52 at Fort Lewis in 1996. It is important to note that the Level II students had varying levels of training: some had been to the U.S. Army’s Sniper School at Fort Benning, Georgia, others had been individually trained by the SOTIC detachment of 1st SFGA, one had attended a Level II course and was there for additional training, and some had no previous training at all. One student was a military policeman from the Fort Lewis SRT team. All operators were able to shoot the .50-caliber rifle to about the same level of precision after they received the position training that is critical to the heavy gun process.

The .50-caliber guns and the SR-25s were also used for a three-day countersniper training program as part of the Level II course. The students received instruction in urban counter/anti-sniper operations in permissive, semi-permissive, and non-permissive environments. Training consisted of surveying techniques, methods of sniper denial, sniper intimidation, and psychological anti-sniper methodology. Among the snipers in the class were some scouts from a conventional infantry unit on Fort Lewis.

Later, one of these individuals, an Army Specialist (E-4), would be the team leader of a sniper element that was in Saudi Arabia when the Khobar towers were bombed in a terrorist attack. This specialist set up a protective countersniper effort and effectively locked down the area. It was heard this young sniper had the full attention of a full bird Army colonel who ensured he was given some special equipment that was required for this effort.

SOTIC AT THE YAKIMA FIRING CENTER

In August 1996, the SOTIC detachment ran its first HTI course at Yakima, Washington. The Yakima Firing Center is a huge training complex used by all the armed services. The complex is large enough for Forward Air Controllers and SF teams to conduct close air support training using Air Force and Navy strike aircraft and live bombs. The good thing about this place is that it is between 2,500 and 3,800 feet above sea level. The air temperatures range from 30 (or worse during the winter) at night to 110 or more during the day. The winds can be dead calm to blasting within minutes. The barometric pressure also fluctuates a lot because of local weather cells that are formed by the Cascade mountain range to the west. It is a great place to conduct advanced, long range sniper training. The targeting support center at Yakima will make you any kind of target you can imagine. They provided the best support we had seen in anyone’s memory in the military.



Digging in the front end to lower the rifle, making it stable.



All 3 guns with Swarovski scopes and SIMRAD mounts in place.



The first gun is a 2nd Ranger Battalion gun with a 16X M-1 ultra scope.

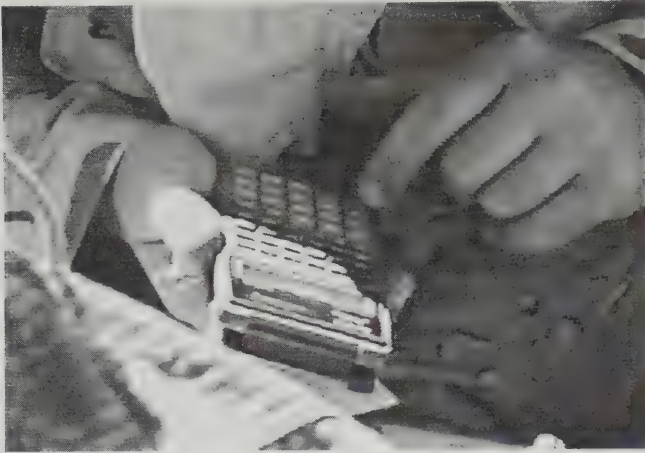


Mix-matched guns, one with the Swarovski and one with the M-1 scope.

Getting Started

Chapter 8 contains more details of the conduct of the course itself. Suffice it to say the days were long. Running a course for the first time in an outlying training area with a staff of three is a tough undertaking. In the end, it was well worth it. The operators thoroughly enjoyed the course and their level of training was pushed way beyond anything they had seen before. It was interesting to see the shooters calculate the corrections for MET and ENV conditions. The guys were shooting at 1,500 meters on the first "long range" day. The targets were M-113 Armored Personnel Carriers that were facing us head-on. The conditions outside resulted in a drop in elevation of about 9.50 MOA. As they were doing their calculations (something they had never heard of before, let alone doing it), there was some head-scratching and looks being passed back and forth. They were used to M-24s with optical sights that used a bullet drop compensator. All they had to do was know the range and dial it in. When they shot, there was a clang on the steel target. So what if the shots were a little low or high?

When they fired their first shots at 1,500 meters and had impacts in the center of their intended targets, smiles abounded. The snipers had spent five days in the classroom doing shooting simulations with calculators and being fed data on the MET conditions. In the afternoons and evenings they were on the range getting their grouping skills down with the big guns. They had now seen the effects of the changes in trajectory from MET and ENV conditions. Non-believers had become believers within five shots out of the gun. The four



An operator makes calculations for his next shot.



M82 on the roof with the shooter behind an SR-25 during exercises.

teams fired day and night for three weeks. They learned how their guns would perform at ranges well past supersonic and shot them anyway, just to collect the data. Instructors got cranky and so did the students. In the end, both instructors and students learned a great deal more about extreme range shooting than they had over the entire course of their sniper careers.

Over and Out

It is said that all good things must come to an end. The staff of the SOTIC committee—Maj. Econ, Sgt. First Class Michaelis, and Staff Sgt. Bevans—was replaced by three new individuals. In 1997, another HTI course was run using full Special Forces A-detachments as the basis for the teams. This worked as well and maybe better than the four-man team format used in 1996. Of course, the other special operations units would have to work out their own format. It is still recommended by the author that the operational minimum is four students and one instructor per team. Early in 1998, in a mass of concern over “padded slots,”³¹ the commanding general of USSOCOM cracked down on padded slots and as a result the SOTIC detachment was the first thing to go. After two years of training snipers in field sniping, HTI, anti/counter sniper operations and some special reconnaissance stuff, SOTIC came to an end. All of the special equipment that was purchased—Swarovski spotting scopes, specialized cleaning gear, shooting stools, etc.—not to mention all the money spent in upgrading the facility, went to waste. It is now boxed up and sitting in storage somewhere at the 1st SFGA compound. I give credit to Maj. Econ and Col. Howard for having the cajones to put the program into action.

This brings us to the current situation within special operations on the status of .50-caliber heavy rifles. As of this writing there is a competition that is in its final stages to find a replacement for all .50-caliber sniper rifles within special operations. After much grumbling the semi-automatic (the Barrett M82A1) was not included



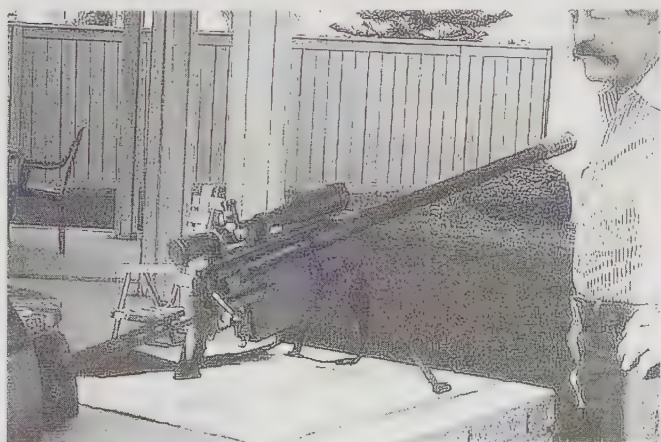
HTI operators rehearsing their team Immediate Action Drills for the final mission rehearsal, Yakima, 1996.

in the testing. The two guns that were in contention for the heavy sniper rifle are the Barrett Model 95 and the EDM Arms Windrunner .50-caliber. I can't make a judgement, as the only one I've used is the M95 Barrett rifle. After spending a good bit of time with the Windrunner, however, that gun seems to hold great promise. It's a masterpiece of engineering, designed and built by an individual that shoots them as well as designs and builds them.

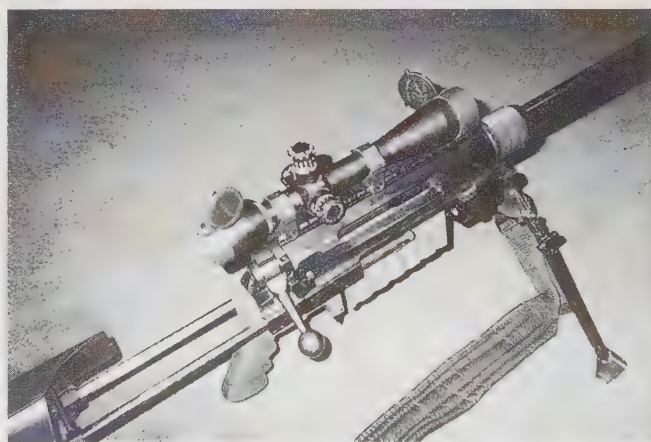
The future of special operations heavy sniping will certainly be in constant change as it is believed that the heavy class of rifle is the most dynamic and exiting of the three classes of sniper rifle.³²

FOOTNOTES

1. U.S. Army Combat Systems Test Activity, Aberdeen Proving Grounds document, paragraph 4. Dated 1 March, 1985. Research Armament Prototypes and Research Armament Industries (RAI) are also known as Reddick Armament Industries.
2. The specification that the rifle fire all types of ammunition, including the M-903 SLAP round, created a problem in the beginning. As the reader will see later in the book, the SLAP round requires a radically different rate of twist than do the rest. In fact, the gun can only be optimally twisted for one type of bullet as they ALL have different specific gravity, a major factor in determining barrel twist rate.
3. Mean radius is a method of measuring the size of a group of shots. For example, 10 shots are fired on a target. The center of the group is determined and then the distance from this center to each of the impacts is measured. These 10 measurements are then averaged and this figure is the "mean radius" of the shot group. The figure should not be confused with the MOA size of a group. Mean radius is a less desirable method of measuring a group's size.
4. Many times specification sheets are specifically written so as to describe only one weapon system on the market. That is because that particular weapon has all the features that are required or desired by the purchasing element. When specifications are that tightly written, it virtually guarantees that only one rifle can possibly fill the requirement. As you will learn in Chapter 5, the angle of the scope base is critical to the system. By writing paragraph 3.7.2 the way they did, they specified a scope base with a 60-MOA tilt to it. Good idea.
5. The instructors made these observations at the time. These are not comments from gunsmiths. While it may appear that the spring compression memory was the problem, it is more likely that the springs may have been of an improper specification. Of the two possible causes, improper spring energy is the most likely cause.
6. Refer to the picture on page 7. The bipod legs fold to the rear. The legs on bipods always should fold to the front. The Harris and Parker-Hale bipods all fold to the front. This allows the shooter to lean into the bipods, therefore "locking the gun up," as is the proper way to shoot a bipod gun. The bipods on these .50-caliber rifles all folded to the rear and front. Bad idea.
7. The RAI rifles were not the only guns to do this. Virtually all guns with the "shellholder" design bolts had these problems at one time or another. They have all since been resolved.
8. The very early models had no safety on them. Shortly after this event, a butterfly safety was added to the back of the bolt. Still, some of the shellholder design bolts had accidental firings before the bolt was fully rotated down.



Bill Ritchie with his creation, The Windrunner .50-caliber rifle.



The updated Windrunner as shown at the 1999 SHOT Show.

9. Stippling the inside of the rings? Imagine the problems this must have caused with the scopes. Suddenly the tension on the scope was generated by several very small stippling points. Stippling is a process where a punch and hammer are used to pound sharp points into the inside ring surface. This has the effect of making many little sharp steel points that grip the scope tube. Current gunsmiths lap in the rings to make an even, tension free grip of the scope tube. The U.S.M.C. method is diametrically opposite the current methodology.
10. One has to wonder why the Weaver T16 was selected for use on these guns. The Unertl target scopes are more durable than the T16 scopes with the external adjustments on the Unertl rings. The Unertl scopes also have/had the elevation capabilities needed for long-range shooting.
11. These are not bad levels of accuracy at all. Note that the gun had a lower level of accuracy at 300 yards than at 1,000 yards. There were some that argued that the bullet had not "settled down" enough at 300 yards to produce good short-range results. At 1,700 yards, it is likely that the bullet was subsonic and therefore lost considerable accuracy. More on this phenomena is in Chapter 6.
12. This test was conducted way back in 1984. It is interesting to note that the same problems still exist as this is being written. Open and vented muzzle brakes have always given away positions and cause such a great atmospheric disturbance in front of the observer that the observer can't do his job. The development of "can"-type suppressors would have resolved that problem, but for some reason never were fully adopted for the big rifles.
13. It is interesting to note that the Marine Corps recognized this problem. The Marine Corps is also the only entity that actually has employment doctrine for the weapon. Army Special Forces has no doctrine and little understanding of the employment capabilities and restrictions of the guns.
14. These are the author-summarized results of the testing. The facts are not altered in any way, but some of the less important information has been removed from the text. This testing has been rendered obsolete by the newer weapons systems in use. The Barrett .50-caliber was never applied to the JMEM manuals. The newer system coming into special operations almost certainly will be used to obtain new JMEM data.
15. In the dimension that the paragraph is referring to, the 1 percent is based on a danger-space figure. The subject of danger space as it relate to range determination is covered in detail in Chapter 7, "Range Determination."
16. Consider that this test was conducted in 1984. You will see in a document by Lawrence Livermore National Laboratories later in this chapter that addresses the same problem in their concept on a 5,000 meter sniper rifle system.
17. To try to put this data into simpler terms, the maximum deflection of the bullet in a steady and non-changing 2-mph wind at 2,000 yards is 52.6 inches. When that wind is anything less than a steady 2-mph, the most that bullet will be deflected is 36.6 inches.
18. The winds are bound to be variable at these extreme ranges. The problem is that the winds may easily fluctuate up or down an average of a certain speed. This is the biggest wind problem in extreme range shooting.
19. One major component that has been left out, though, is the shooter-input effects of muscling the large-bore guns with the attached muzzle brake. There is definitely an effect from not neutrally shooting the gun. See Chapter 4 for details on this effect. It is quite possible that this human-induced factor is the largest factor of all on extreme spread.
20. This concurs with the result of the unofficial U.S.M.C. test previously mentioned.
21. What they are referring to here is the fact that the .50-caliber projectile is not all that effective in long-range conditions. The effects of barometric pressure and air temperature changes are too great. Chapter 6 covers the detailed methods used to handle these changes.
22. While the EX211, Mod-0 round of that time was not as accurate as it is now, the M-33 Ball round was simply atrocious. Bullet runout, poor bullet construction and extreme muzzle velocity variations are some of the major factors affecting accuracy. Combining the two cartridges results into one, contaminating the results. The EX211 round loses some ground in accuracy, while the M-33 Ball round unfairly gains ground.
23. Quoted from the H.P. White test, dated August 1985.
24. It is interesting to note that the clamp of the fixture grasped the very assembly that contains the "tuning rod" feature of the gun. May it be possible that the fixture's gripping of this assembly actually changed the dampening properties of the system?
25. This information was compared against the unofficial U.S.M.C. test conducted. The Marines stated in sub-paragraph b.2 and 3. "The stock is adjustable and is readily accepted." "The cheekpiece is adjustable for height and that feature in itself is well accepted."
26. It is not clear which previous firings the test is referring to. In the U.S.M.C. test, shoulder-fired weapons had a much better accuracy capability.
27. Refer to Chapter 4 for the results of this training. The author kept notes on observation of the training and the ability of the "trained" snipers to shoot the big guns.
28. The author has never had this problem with any M500 or M600 series rifles. That is not to say it has not happened, only that the author has never heard of this type of mishap.
29. Author's Note: The last part of this statement is a little odd. Rarely will a gun system fire more accurately than test barrels that are used for lot acceptance. Not sure what Crane meant by that statement?
30. Source: John Ferry retired Warrant Officer, U.S. Army Ordnance Corps.

MILITARY HISTORY OF HARD-TARGET INTERDICTION AND ITS DEVELOPMENT IN SPECIAL OPERATIONS

31. Padding slots is the practice of putting operational people on staff jobs to beef up the staff. At one time, the 1st SFGA had over 50 pad slots. Team strength was about 7-9 on the average.

32. The three classes of sniper rifle are:

The light class, which is any Sniper Weapons System up to and including 7.62mm NATO. Examples of this class include heavy-barrel 5.56mm guns and the M-24.

The medium class, which is any caliber larger than 7.62mm up to but not including the .50-caliber BMG. Examples include the .300 Winchester Magnum, .338 Lapua Magnum, and .338/.378.

The heavy class, which is the .50-caliber BMG and larger.

CHAPTER 2

Equipment Used in Hard-Target Interdiction

The equipment used in HTI is both quite similar and yet quite different than that used in standard sniper operations. You use rifles, but these are bigger and heavier and pack a bigger punch. The operators still use range-finding instruments, but some of the methods used here mix age-old angle-reading methods with modern technology. These systems include things that have been used within the military and some that were outside the military but have been tried out. The equipment is broken down into four categories:

- Heavy Class Rifles
- Day Optical Sights and Observation Scopes
- Night Sight Systems and Night Observation Scopes
- Supporting Technology

THE GUNS OF HARD-TARGET INTERDICTION

The term heavy-class gun comes from a Special Operations Command (SOCOM) document outlining a family of sniper weapons systems for use within special operations. By definition, heavy-class guns are .50 caliber and larger and are intended for anti-materiel interdiction. The following is not intended as an evaluation of the items mentioned—some strong points are pointed out, as are weak points of the individual systems, but these points are based on the author's experience with the weapons that are mentioned. The author has not personally used all the systems listed.

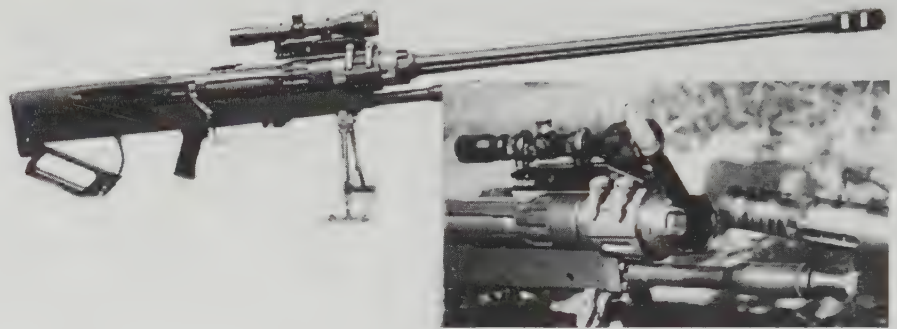
Aerotek

Aerotek's new pair of heavy sniper rifles is offered in a pair of United States and Commonwealth of Independent States (CIS) cartridges. The 14.5 x 114mm (CIS) and the 20 x 82mm (U.S.) are a pair of heavyweights that are a great contrast in performance. As can be seen in the inset in the photograph the operator can switch barrels by using the base of the cartridge on the barrel nut. The 14.5mm cartridge fires a

930-grain projectile (B-32 Round) at a velocity of 3,230 fps, which is good performance. The 20mm cartridge fires a 3,160-grain projectile at a velocity of 2,360 fps. This is a very heavy and slow-flying bullet. What this means is that while there is tremendous power behind this projectile, the range to the target must be precise, as the danger-space dimension will be very short. The optics system on this gun is a long eye relief 8 x 42mm scope with adjustable parallax. It is fitted with a bullet drop compensator (BDC). But because of the projectile's low ballistic coefficient and low velocity it is easily affected by meteorological conditions. The effects of barometric pressure, air temperature, and ammo temperature will greatly affect the trajectory of the 20mm round.



Aerotek NTW 20mm



Aerotek NTW 14.5mm

Daisy and Earl Reddick

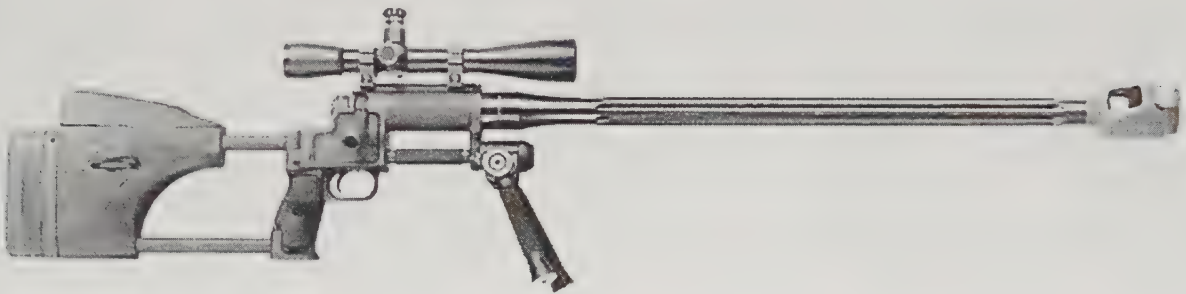
The Daisy Model 600 rifle is a gun that was developed by Daisy and Earl Reddick in 1987. Mr. Reddick worked at Daisy for a period and together three models of the M600 were built. These were in .50-caliber Browning, 14.5 x 114mm Soviet, and 12.7 x 107mm Soviet. The 14.5mm gun is a scaled-up .50-caliber version with the biggest visual difference being the size of the muzzle brake. All three versions are single shot, bolt face loaded rifles. They were standard equipped with Leupold & Stevens M-1 Ultra in 16X (now known as the Mark IV, M-1) unless otherwise specified. The bases on these guns were tapered to 60 MOA or 1



Daisy Model 600 14.5 x 114mm



RAI M500 .50-caliber rifle.



Daisy M600 Standard

degree. The weight of these guns is approximately 26 pounds for the .50 caliber versions and 36 pounds for the 14.5mm version.

Earl Reddick has a long and distinguished history in development and building heavy-class rifles. He is one of the early pioneers and stands with Gale McMillan, State Arms, and a couple of others. The rifles he built are still in service in some places. These photos show one of the earliest produced.

This rifle eventually became the M600. One major feature of this gun is the extension that is under the barrel off the front of the receiver. This extension contains a tension rod that runs the length of the tube. On the inside bottom of the receiver is a large screw slot for tuning this tension rod. The concept is that this rod serves as a kind of tuning fork. It is intended to offset the harmonic vibrations set up in the barrel when shooting. When it was tuned right, it worked very well.

One of the problems when these guns hit the Army Special Forces units in the mid 1980s was that there was no operator training in their use. Armorers and operators alike assumed that this cross-slot screw was to hold the extension under the barrel tight. They assumed that this extension's sole purpose was to hold the bipod legs. The result was that this screw would be tightened by well-intending personnel. This completely threw the tuning out of order on the rod. This rifle is a single shot that loads the cartridge on the face of the

bolt. This method of holding the cartridge made more than one operator nervous as he rotated the bolt down. The possibility of the round going off when the bolt closed was always present. One manufacturer had this very problem, but none of the RAI guns ever did to the author's knowledge.

Barrett

Barrett Manufacturing is another member of the early heavy-gun developing leaders. While everyone else was working with bolt action guns, Ronnie Barrett went the way of the semi-automatic. In function, the M82A1 and M82A2 are quite similar to the .50-caliber machine gun. It is a short recoil, blowback system. When fired, the barrel strokes about 2 inches to the rear. This then drives the bolt backward, extracting and ejecting the brass and stripping the next round off a 5- or 10-round magazine.

A suppressed version of this gun was developed. There is a problem with heavier recoil, and an increase in bolt velocity that blows extractors off the bolt face. While it is a fun gun to shoot, most operators preferred a bolt-action system because of problems caused with this gun's accuracy. Also, the gun is not exactly ergonomically built. The weapon is taken apart by removing two pins in the front and rear of the receiver.



M82A1 rifle of the 2nd Ranger Battalion, issued with the 16X M-1 Ultra scope. Note the hard chrome finished bolt and the SIMRAD mount of the scope.



A later version of the M82A1 rifle issued with the Swarovski 10X scope with the "Christmas tree" reticle pattern. Note the black finished bolt on this gun. Also note two different operators with identical shooting positions as taught in HTI methods.

These takedown pins do not bear load or recoil. The muzzle brakes on all of the Barrett rifles are quite efficient. They are a simple design and to most operators feel like they do the best job of cutting down recoil. But they are not the best at blast control, as in dust eruption at the gun position.

The new Barrett M82A2 was shown at the SHOT Show in Atlanta in February 1999. The new gun has an aluminum receiver that dropped the weight by about 9 pounds. A new magazine design (synthetic vs. metal) sports a curved shape, and the iron sights received a much-needed upgrade. The big eye-catcher of the



SOTIC, 1st SFGA mod to M82A1 with PSG-1 type pistol grip and 16X optics.



Model 99 "BIGSHOT" single shot.

gun was the Picatinny-style rail running the length of the receiver. The rail's scope base contains lithium flat batteries. The pistol grip appears to have more of an arch to it also. Ronnie Barrett also released a new bolt-action rifle at the show. The Model 99 is a single-shot .50 caliber rifle intended for the more economical purchaser. The rifle is light and well balanced, and features a 33-inch barrel that reaches considerably higher velocities than the M82 guns do. The receiver is a solid one-piece extrusion. The locking lugs on the bolt are very non-traditional—the bolt is essentially like a true threaded bolt and the locking lug area of the barrel is like a nut. The difference is that the threads are interrupted on the bolt. These interrupted threads rotate with the bolt handle and engage interrupted threads in the lug area of the barrel, locking the two together. The fluting on the barrel is very different from previous versions. There are more flutes and they are less aggressively cut into the barrel. Barrett also showed a rather innovative set of scope rings at the show. These rings are adjustable for the angle of the scope. You can set the angle so that parallel bore can be achieved with any scope used. The parallel-bore process is explained in Chapter 5.

Gale McMillan

Gale McMillan's entry into the .50-caliber program begins in 1986/1987. In an article in *SWAT* magazine (May 1987), Gale said he built his first .50-caliber gun in just about two weeks. Dubbed the M87, the gun was a single-shot rifle. It has rebated twin locking lugs, a plunger-style ejector and a Sako-style extractor. Naval Special Warfare purchased several of the M-88 rifles. The M-88 is a single-shot takedown rifle. The round



M82A2 Barrett



M88 with 5th Special Forces Group sniper in Saudi Arabia, 1991.



M88 with a later development—a cone brake.

loads onto the bolt face the same way as the RAI rifles do. These rifles come apart forward of the pistol grip for movement, leaving the area from the bolt forward as the longest piece. Barrel length is 29 inches. The scope bases on these guns were tilted to a 1-degree angle. The M-88 was delivered with Leupold & Stevens M-1 Ultra 16X scopes as the standard optic. The rifles had adjustable cheekpieces and three-way adjustable buttplates installed. The Parker Hale bipod was attached to a stud in the front of the stock's forearm.

McMillan Gunworks eventually became Harris Gunworks in a sellout to Wes Harris. Soon another rifle company with Gale McMillan in the system started building some very state-of-the-art rifles. He built the actions as he always did. McMillan's actions are used on Robar, Lazonronni (they build no .50-caliber guns), K&P, and a number of smaller custom builders.

The three McMillan or McBros rifles on the following page represent two tactical systems and one competition .50-caliber system. The takedown version at the top is a single-shot, bolt face





loaded rifle. The action of the bolt face loaded guns is much shorter than the single shots like the M87 or the repeater guns. To have a loading and ejection port, the action must be made longer to accommodate the length of the loaded cartridge. By using a takedown stock and a bolt face loaded receiver, the overall length of the gun is reduced as much as possible without shortening the barrel.

The repeater rifle has a 5-shot magazine. As a result of being a repeater, the action is longer than on the takedown guns. Both guns use an adjustable length of pull (LOP) system that uses spacers to change the LOP. Both guns use a lower profile muzzle brake that vents to the sides. The bipod on these guns is similar to the Parker Hale but is of McMillan's design. The competition bench rest rifle in the picture is a right-hand operated bolt but with the ejection port on the left side. This is done so that the shooter has to make minimum movements with the right hand while loading with the left. Tactically speaking, this method greatly cuts down loading time. In single-shot guns, you have to eject the expended brass, reload a live round, and then close the bolt. With this "mixed up" action, you can do both at once, effectively cutting in half your shot-to-shot time.

When McMillan was developing the original .50 caliber guns, one of his stated philosophies was that the gun should "feel" the same as any other rifle in the hands of the shooter. His M87 was essentially a much scaled-up M86 .308 gun. When you put one of the M87s on your shoulder, they do feel the same. You notice the difference in the balance of the gun and the stock feels a bit wider on your shoulder. The McMillan rifles have always been regarded as some of the best designed and best shooting guns in the heavy class. The McMillan action is the most proliferated action among other gunsmiths in the United States.

Pauza P-50

The Pauza P-50 made its premier in 1988. The gun is a gas-operated, semi-automatic



Pauza P-50



Robar RC-50 and the Robar RC-50-F.

repeater. It is fed from a 5-shot magazine. The design of the gun is based on the old Soviet Simonov design from World War II. The receiver is machined from a solid billet of 4130 steel. The flat design of the muzzle brake seems to keep the disruption at the sniper's position down more than the clamshell design brakes. It is a little better than the arrowhead design used on the Barrett rifles. Ergonomically, the gun is a compromise between design and fit for the shooter. The bipod appears to be attached to the barrel, but this is not the case. The bipod is attached to a mounting bar that extends from the receiver forward. The barrel length is 29 inches. The pistol grip is borrowed from the M-16 design and is an ergonomic compromise. With the creation of all the different specialized pistol grips out there; one would consider upgrading these handles to something a bit more shooter-friendly.

Robar

Robar is one of the manufacturers that uses McMillan's .50-caliber action. The pictures show one of Robar's camouflage finishes. While other takedown methods involve the separation of two pieces of the gun, the Robar RC-50-F is hinged to fold to the side. For an operator who is rigging this gun for a jump, this additional bulk is not desirable. However, with a little engineering the buttstock can be totally removed and replaced with a floating pin. This makes the piece totally removable. These guns have virtually the same operational characteristics as the McMillan rifles. They weigh approximately 25 pounds. The gun's finish is Robar's NP3 on the bolt and magazine follower. A non-slip finish is applied to the critical "touch" areas of the rifle, and custom camouflage is available with Robar's proprietary "Polymax" finish.



Knight's Armament SR-50



American Arms & Ordnance M2000 M/P .50-caliber repeater.

SR-50

According to the manufacturer's brochure, the SR-50 is Eugene Stoner's final design. The gun is a semi-automatic, gas-operated repeating rifle. Magazine capacity is 5 rounds. This rifle presents some of the same operator ergonomics problems that all of the semi-automatics seem to have—it retains the M-16 pistol grip that the Barrett and the Pauza have (which is uncomfortable for the sniper, who must stay in position for lengthy periods) and the cheekpiece is a piece of round steel. Night-vision systems such as the Aquila and the M-995 Night Ranger have a higher mounting level. This requires the operator to raise his

face off the stock, destroying the concept of spot weld of the cheek to the gun. This picture shows a SIMRAD mount on the day scope. The gun was seen at the SHOT Show in 1999. Charles Poff, formerly of American Arms & Ordnance was on hand to describe the rifle to show attendees.

American Arms

American Arms uses a unique bolt locking lug design. The locking lugs lock up on a 45 degree angle instead of the traditional 90 degree angle. This provides superior strength in that area. The result is that the gun can use much higher energy designed rounds and not shear or move the locking lugs. The gun has a very fast lock time of 190 milliseconds. Barrel length is 30 inches with a 1:15 twist rate. The stock is cast in aircraft alloy aluminum and does not have a traditional bedding. Instead, the receiver is bolted into a V-block that is part of the cast stock. The muzzle brake on this gun was specifically designed to reduce projectile yaw and the disruption caused by the blast across the surface of the ground. The weight without the optics is 24 pounds.

Armalite

A new entry into the .50 caliber market is by Armalite. This company produces fine 7.62mm and 5.56mm rack grade and match-grade semi-automatic rifles based on the AR-10 and AR-15 rifles. The AR-50 is Armalite's newest gun. It was seen for the first time at the SHOT Show in Atlanta. Mark Westrum, Armalite's

president, said the gun was designed to be low-cost and directed at the entry-level shooter into .50 caliber shooting. The cost is a very reasonable \$2,250.00 retail. As can be seen in the drawing the stock is of a new design. The action is not bedded in the conventional sense. The round receiver is laid and bolted into a V-block that is part of the stock itself. The design is similar but not a copy of the Accuracy International method.

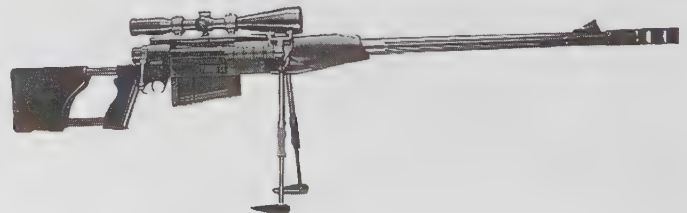


Armalite AR-50 single shot.

The barrel length is 31 inches, with 8-groove rifling and a twist of 1:15. The bolt has three locking lugs and is a single-shot receiver. The weight as listed in the brochure is 29 pounds, but at the show, the stated weight was closer to 40 pounds. The scope base is offered with an angle of 20 minutes, but the option is available for a 75 MOA base so that the parallel bore process can be used with the Leupold & Stevens Mark IV, M-1 scope. The buttstock is removable, but not in as rapid fashion as the McMillan takedown or the Robar RC50-F. One feature the AR-50 has that is sorely lacking on many .50 caliber guns is an adjustable cheekpiece. This is a very welcome feature.

Advanced Weapons Technologies

Advanced Weapons Technologies of Greece offers their initial entry into the .50 caliber foray. The action is based on the Mauser M98 action, although clearly upscaled. A third locking lug is added in the rear section of the bolt. The ejector is receiver mounted similarly to a Sako. The rifle is offered in both 12.7 x 99mm (U.S.) and 12.7 x 108mm (DsHK). Listed velocities are 2,913 fps for U.S. and 2,690 fps for the Soviet cartridge. Barrel length is 42 inches Soviet and 35 13/16 inches for the Browning cartridge. Weight is 35 pounds for the Soviet round and 32 pounds for the BMG round. When the rifle is setting on the ground, it is perfectly balanced on the bipod legs. The tail



The AWT .50-caliber Black Arrow.



Iver Johnson M500 .50-caliber single-shot rifle.

floats up in the air and the gun sets evenly on the bipod legs. This is actually a problem in that when the shooter is behind the gun, a heavier tail makes it more stable. When the gun is this well balanced, the front is going to float too much on the target. A good balance in guns seems to be about 3-4 pounds over the tail section of the gun. The barrel on these is a blend of chrome, nickel and vanadium steel originally designed for

high velocity tank cannons. There are two spring recoil compensators in the stock in addition to the muzzle brake for handling the recoil.

Iver Johnson, Inc.

The Iver Johnson/RAI M500 rifle (built by Iver Johnson) is the original gun as supplied to U.S. Army Special Operations Command. This is the same gun as previously mentioned under the RAI section. This gun uses the same tuning-fork principle in the extension off the receiver. They were originally supplied with Weaver T-16 scopes that were not durable enough and did not give the long-range elevation travel needed to engage targets at 1,500 meters. The T-16 was soon replaced with Leupold & Stevens M-1 Ultra scopes. The scope base on this gun is actually two pieces. There is a rail permanently attached to the receiver. The scope base itself has two spring loaded clamps that interface with the base on the receiver. The two scope rings are bolted into the base with the spring-loaded clamps. The system was very durable and tough, if not very heavy. The barrel length is 33 inches and it is heavily fluted the length of the barrel.

Harris Gunworks

The Harris Gunworks M-96 is another gas-operated, semi-automatic repeating rifle. The rifle is very similar to the Pauza P-50. The only real visible difference is the mounting method for the bipod, a little difference in the magazine slot, and the scope mount/carrying handle for the gun. The muzzle brake of course is Harris' design. It is a cone-type brake that is quite efficient and has considerable disruption of the ground at the muzzle.

EDM Arms

At the time of this writing, EDM Arms is one of the two manufacturers making rifles for the USSOCOM heavy-rifle contract. In competition with EDM's Windrunner is the new Barrett M95 bolt-action rifle. The two are radically different guns. (One can view these guns on the Internet at WWW.FirstDefense.com.)

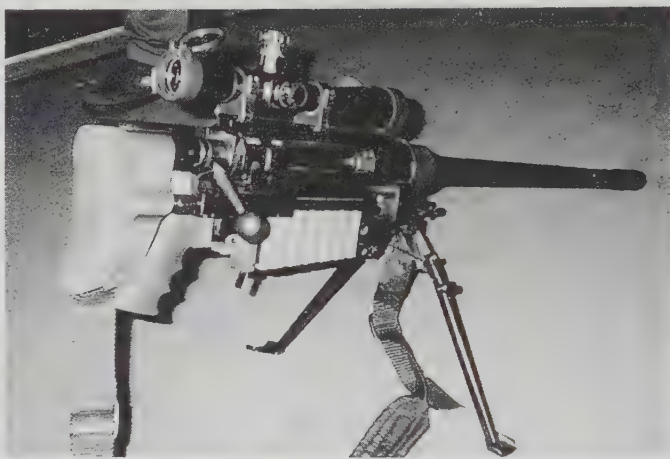
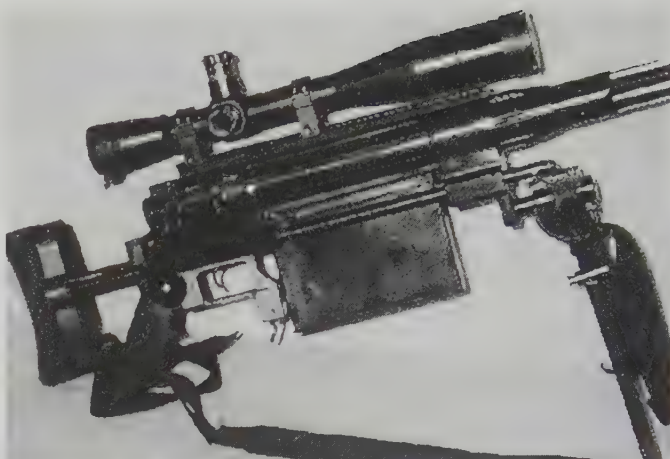


Harris Gunworks M-96 semi-automatic receiver.

Designed and built by Bill Ritchie of EDM Arms, they are a revolutionary design incorporating the most advanced engineering and construction methods. The barrel is removable by the operator by turning the Uzi-style barrel nut by hand and removing the barrel. EDM Arms uses very high precision machining techniques that allow barrels to be interchanged at operator level. The action proper is electro-discharge machined (EDM) from a billet of aluminum. A steel component is then inserted into the aluminum receiver for the locking lugs of the bolt to engage. This greatly reduces the weight of this gun. Most of the weight of the Windrunner is in the barrel itself. It is massive and it is deeply fluted. The bolt function on this gun is one of the smoothest that this author has encountered. Its every bit as smooth (probably more in direct comparison) as a 30/40 Krag-Jorgensen gun. The rotation is oily smooth and there is little lock down tension caused by the cocking action. The rifle has an adjustable cheekpiece that moves up and down as well as back and forth along the stock. This allows the user to compensate for any optical system that might be used on the rifle. The scope base is angled at 60 minutes or 1 degree. Using the Match Grade ammunition designed for this rifle, a representative from First Defense shot a 1/2 MOA group measured at 1,004 yards. This is a claimed world record. The rifle also fits into an offered 34-inch Pelican-style hardcase. The .50/20mm Warlock rifles by EDM use a 20mm cartridge necked down to .50 caliber. While the rifle has great promise as an HTI rifle, there is little government interest, at least in the United States. The scope on this gun is the United States Optics Technologies SN-6. There are no details available on this gun. EDM Arms still has a few of the actions lying around and will build a gun if asked to.

Steyr-Mannlicher

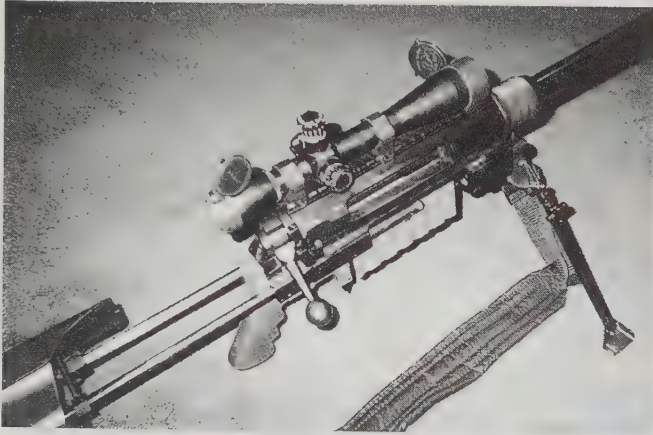
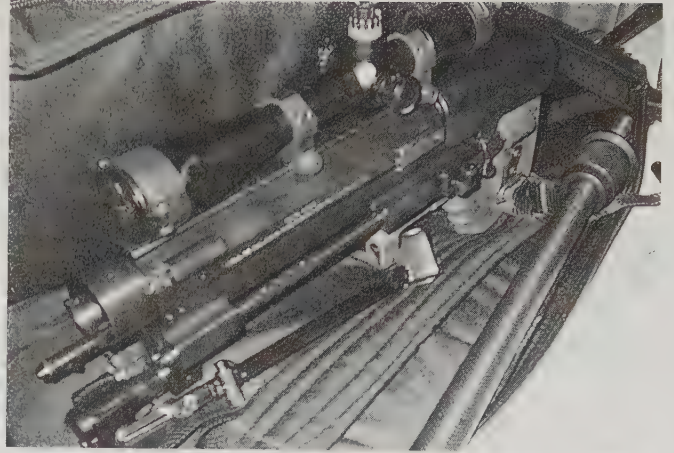
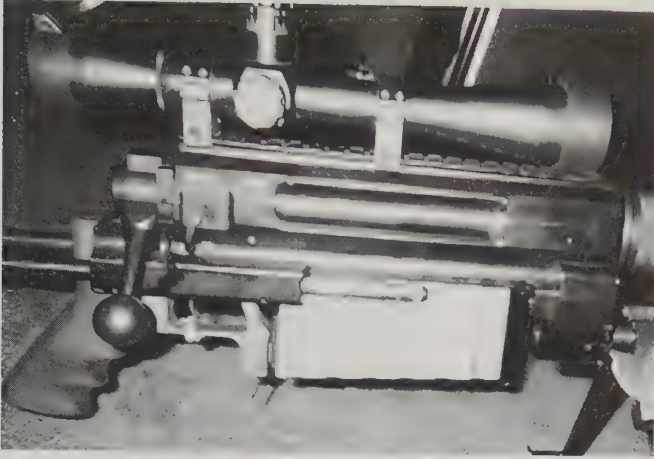
Austria's Steyr-Mannlicher created a huge anti-materiel rifle, the IWS 2000, that was seen here and there in 1996. This gun simply is huge and really is not man-portable unless it is carried by a larger element (6 or more) to break down its load and supporting systems. It certainly is capable of the task based on the revolutionary ammunition that it shoots. The gun is a 15.2mm (.60 caliber) rifle that



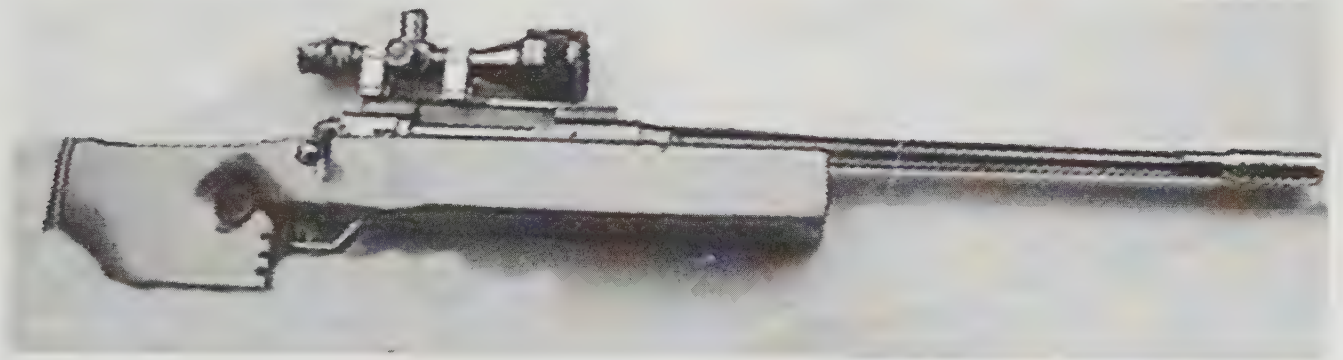
WINDRUNNER SPECIFICATIONS

- **Weight = 29 lbs. Standard Gun**
- **Barrel Length = 28", 8-groove with a 1:15 twist ratio.**
- **Velocity of 2878 fps achieved with a Mance 765-grain steel bore riding bullet. (World Record @ 1000 yds = 1/2 MOA).**
- **5-shot inline magazine.**
- **Breaks down to less than 28" overall (limited by barrel length)**

EQUIPMENT USED IN HARD-TARGET INTERDICTION



Images from the 1999 Shot Show in Atlanta.



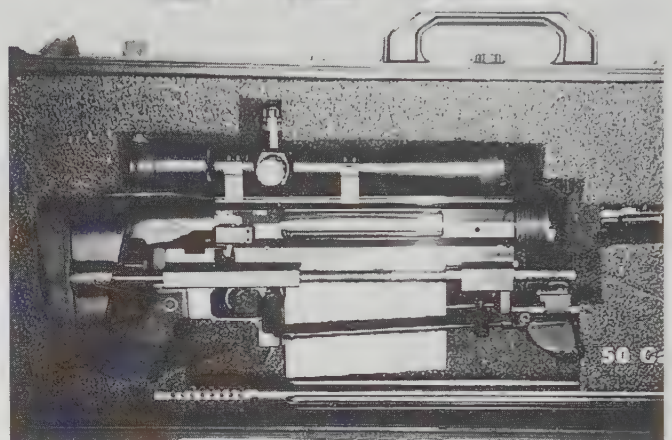
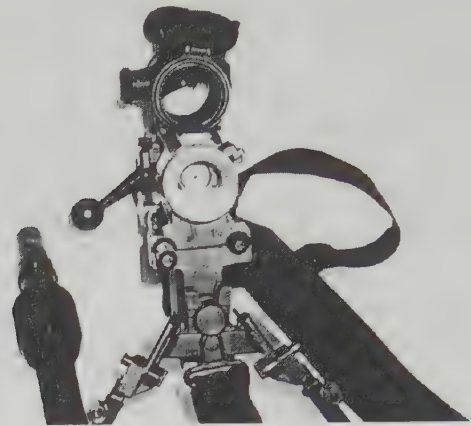
EDM Arms .50-caliber Warlock .50/20mm rifle.



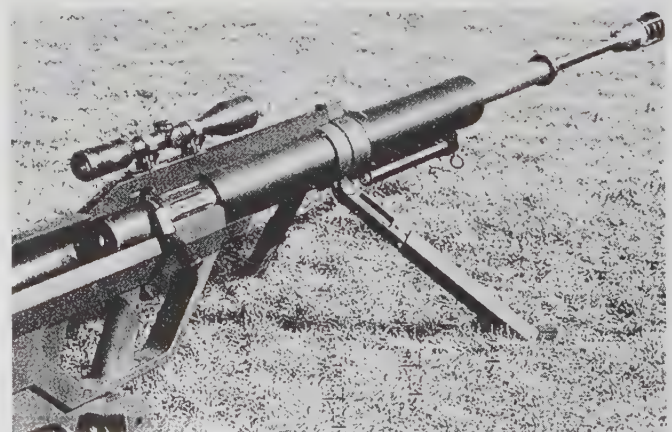
weighs in at 80 pounds. The rifle is 71 inches long and is broken down into two sections that weigh 40 pounds each.

An HTI team would have to cross-load the entire team's mission load to accommodate carrying this gun. The possibility of carrying more than one rifle is also out of the question. The rifle fires a round that resembles a tank round more than a rifle round. The round is an Armor-Piercing Fin-Stabilized, Discarding Sabot (APFSDS). It shoots a .300 grain steel penetrator at a velocity of 4,760 fps. Recoil compensation is handled with a muzzle brake and the operation of the action takes care of the rest. When the rifle is fired, the bolt automatically rotates and moves to the rear of the action. This process ejects the spent cartridge automatically. The bolt remains open and is ready to be reloaded with a single round. In an article in *Special Weapons for Military & Police* (1996), the recoil was said to be like that of a .243 rifle.

The ammunition is purpose-built for this rifle alone. The barrel is a smoothbore, just like that of a tank cannon. The penetrator is fin-stabilized and is encased in a 4-petal sabot with a pusher plate. Steyr has solved the problem of muzzle brakes capturing parts of the Sabot cup. These problems happen on all of the guns built in the U.S. when firing the M-903 Saboted Light Armor Piercing round. The synthetic sabot components have much lower friction in the bore because of the material and the fact that there is no rifling for a guiding metal jacket to engrave as a conventional bullet travels down the bore. This also lowers the recoil of the gun. Barrel life is said by the manufacturer to be indefinite because of the lower friction and heat in the bore. Penetration ability is

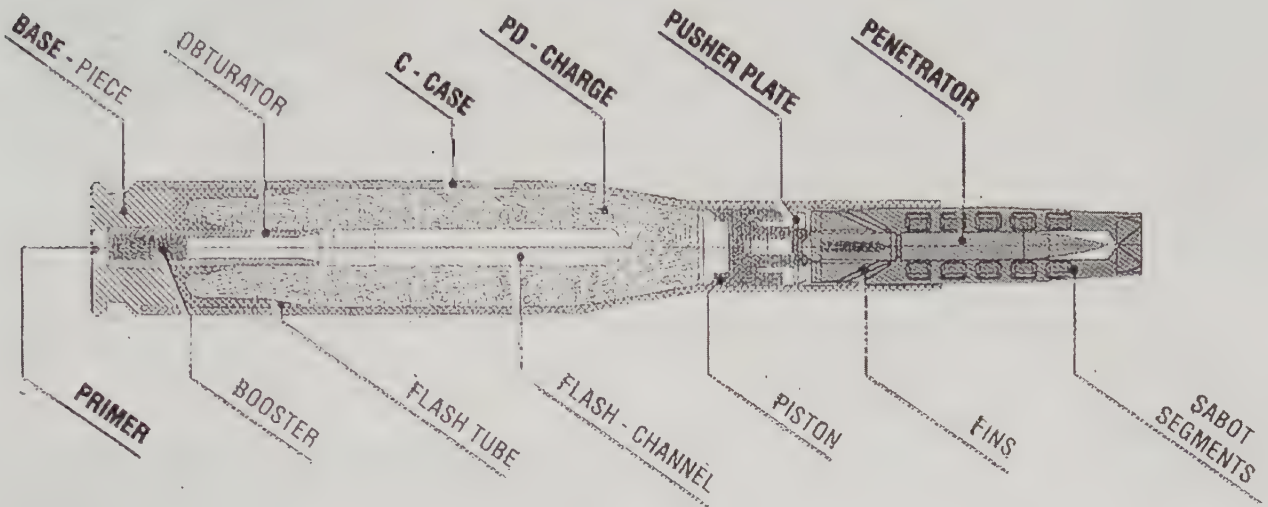


The Windrunner rifle in its 34-inch case. The rifle is also shown with the round of ammunition designed for it and with the barrel removed. The face of the bolt shows through the front of the action. This shows the precision mating surfaces where the barrel interfaces with the action.



Steyr IWS 2000 15.2mm AMR rifle.

THE 15.2 mm APFSDS - ROUND



The 15.2mm APFSDS round.

claimed to be 1.57 inches of tank armor at 2,000 meters. In the development version of the gun, the rifle was able to strike a 20-inch-square plate at 1,000 meters (less than 2 MOA). Steyr did not build the rifle for special operations missions. It was made for their infantry to have an anti-materiel rifle. The infantry have the manpower or vehicle power to move such a weapon around.

Certainly, this section did not cover all of the heavy-class rifles that are built around the world. These are the major systems that have been brought to the United States or have been built here. Due to the limited size of this chapter to allow for more detailed information later in the book, some of the lesser-known systems have been left out.

DAYTIME OPTICAL SIGHTS USED ON HEAVY RIFLES

The daytime optical sights for use on these rifles must be of the highest quality to withstand the abuse of recoil and muzzle blast shock. Many have been tried and a few stand out. These optics are all very expensive. A good portion of the scopes cost over \$1,000.00 apiece and some get as high as \$2,000.00 and more. As any serious hunter, sniper, or competition shooter knows, sights are not the place to compromise on cost. On many sniper weapons systems and competition guns, the cost of the optics is greater than the cost of the guns themselves. Mounting systems that repeat zero perfectly also cost a couple of hundred dollars. This is not intended as a product evaluation, however, strong and weak points are pointed out based on experience and observations.



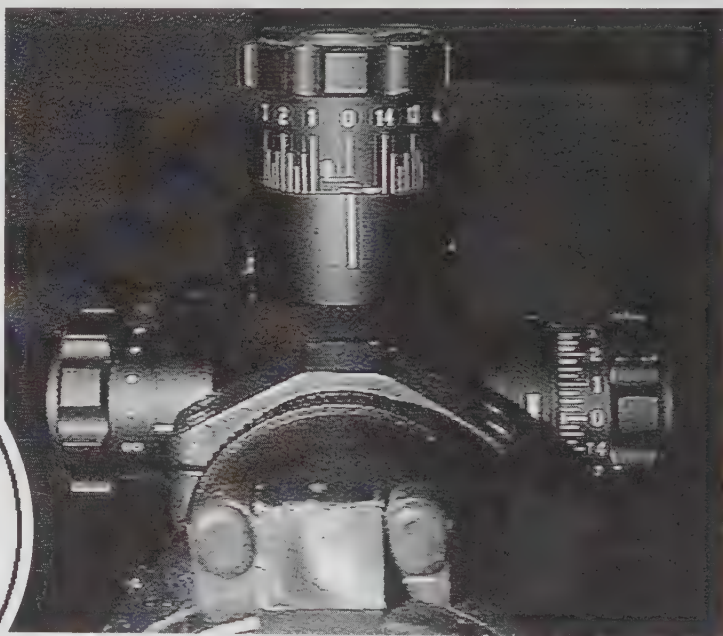
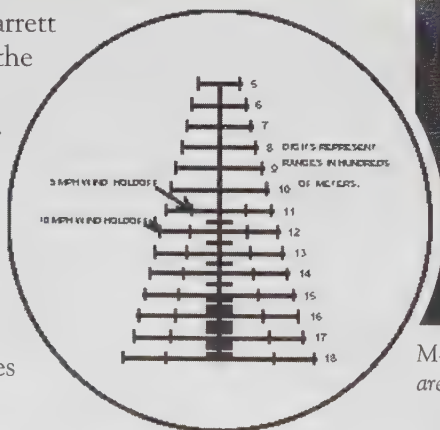
Leupold & Stevens M-1 Ultra and Mark IV, M-1

Without a doubt the most proliferated tactical grade scope used on long-range sniper rifles and in many types of competition is the L&S M-1 series scopes. With the possible exception of the Barrett rifles, every manufacturer pictures their rifles with the M-1 optics mounted on top of them. There is good reason for this. They are durable, operator friendly (when you understand the values of the numbers on the knobs), and combat proven. The M-1 scopes come in two models, the 10X with 90 MOA of elevation travel and the 16X version with 150 MOA total elevation travel. The technical specifications and zero procedures for this scope are in Chapter 5. When mated with the Mark IV rings and bases, or bases of the same design, this system makes a durable, return-to-zero optical system that is considered the standard in long range optics today. The ring design of the Mark IV is rapidly becoming the most copied in the industry. Take a look through the Brownell's catalog and you will see for yourself. A 20X version was built for the Navy for a while, but was not offered to the general public. Eye relief is a critically narrow band with the 16X.

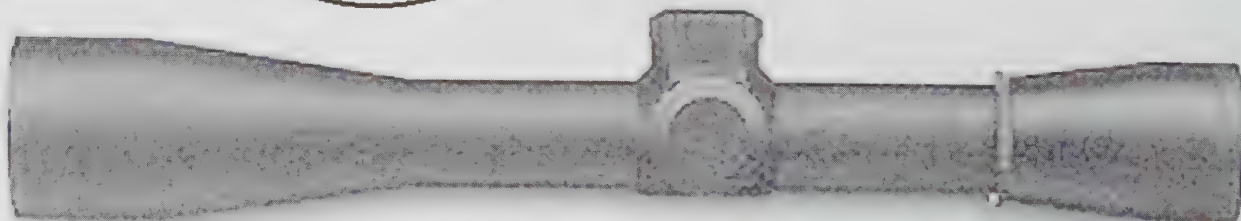
Leupold & Stevens M-3A Ultra and Mark IV, M-3

The M-3A (military designation before the Mark IV designation) and the Mark IV, M-3 are rarely found on heavy-class rifles. The scope body has a diameter of 30mm. The objective is 40mm in diameter. There is a parallax adjustment on the left side of the scope. Elevation "clicks" are 1 MOA. The windage is 1/2 MOA per click. These scopes are set up with a Bullet Drop Compensator (BDC). As you will see later in Chapter 5, BDCs do not have a place in extreme-range shooting. The effects on a previously plotted trajectory by ENV and MET conditions are too great to generalize the elevation settings by using settings in hundreds of meters. The Barrett

M82 is one of the few guns that uses this scope. The BDC knob, however, is NOT used to set the different elevation values



M-1 set at PBZ with a data bottom of +30 MOA on the scope. All come-ups are started at this point of the scope.



Mark 4 M3-10x40mm (matte).



on the scope. The BDC knob is blank when it is on the Barrett rifle. It is used for zeroing the rifle at 500 meters.

The elevation setting is done with the reticle pattern. This reticle is for the M-33 Ball round of ammunition. This round is NOT the standard that is used anywhere in the sniping community. The different military rounds all have variations in their trajectories that demand a more accurate way of indexing elevation values than with a reticle pattern. The details on this scope are found in Chapter 5.

Leupold & Stevens M-1 Long Range

This is a new scope from Leupold. The M-1 Long Range is an enhanced version of the variable power Vari-X III scope. It has Mark IV, M-1 elevation and windage knobs and has a covered parallax adjustment similar to the M-3. The tube is 30mm in diameter and the objective is 40mm. Elevation travel is 90 MOA only with no version offering 150 MOA of elevation. The cost is considerably less than the Mark IV scopes, which generally indicates somewhat lower quality. You get what you pay for, after all.

United States Optics Technologies, Inc.

U.S. Optics is taking a little different approach to putting optical sights on the market. Their optics are custom made with more options available than a local Chevy dealer. While each of their scopes are made for a specific purpose, they have the versatility to reach across that focused intent. With the correct options, any one of their nine optical systems can be used on heavy-class rifles. Their standard scope format is with a 30mm tube diameter and a 58mm objective. While trying not to sound like a U.S. Optics representative, here are some of their strong and interesting points.

- Choice of high or ultra-high resolution lenses. Lens resolution is at 100 line pairs per millimeter. Most scopes out there can resolve only 50-line pair/mm.
- Light-enhanced reticles.
- Objective lens diameters to 88mm.
- Tube diameters to 50mm.
- Choice of front or rear focal-plane reticles. You must use a front focal plane reticle when using the Mil Dot reticles or any range finding reticle pattern. If the reticle is in the rear focal plane, the mils have their true value at only one power setting.
- 200 possible reticle patterns.
- Choice of colors for metal finishes.
- MOA per click value from 1/50th to 1 MOA.
- Recompressed, high-grade optical glass used throughout.
- Infrared, thermal, and light amplification night vision systems available.
- Elevation erector travel up to 300 MOA (with larger diameter tube bodies). Erector travel is dependent on the tube diameter.

U.S. Optics SN-1 series

The U.S. Optics SN-1 scope is designed for the long-range military or police sniper/marksman. It is a fixed power format available in 9.6x, 16.2x, 22.4x and 37x. Each click of elevation equals 1/4 MOA. The model in the picture has an adjustable objective. Tubes are available from 30 to 50mm and objectives from 44 to 100mm. Up to 300 MOA of elevation travel is available with the larger tube diameters. All U.S. Optics scopes can use the Mark IV rings or rings of their own design as seen later in this chapter. Price range is from \$1,600.00 for the basic SN-1 to \$2,900.00 for the SN-1 with 48x, 30mm tube and 58mm objective diameters.



U.S. Optics SN-1/TAR long-range scope.

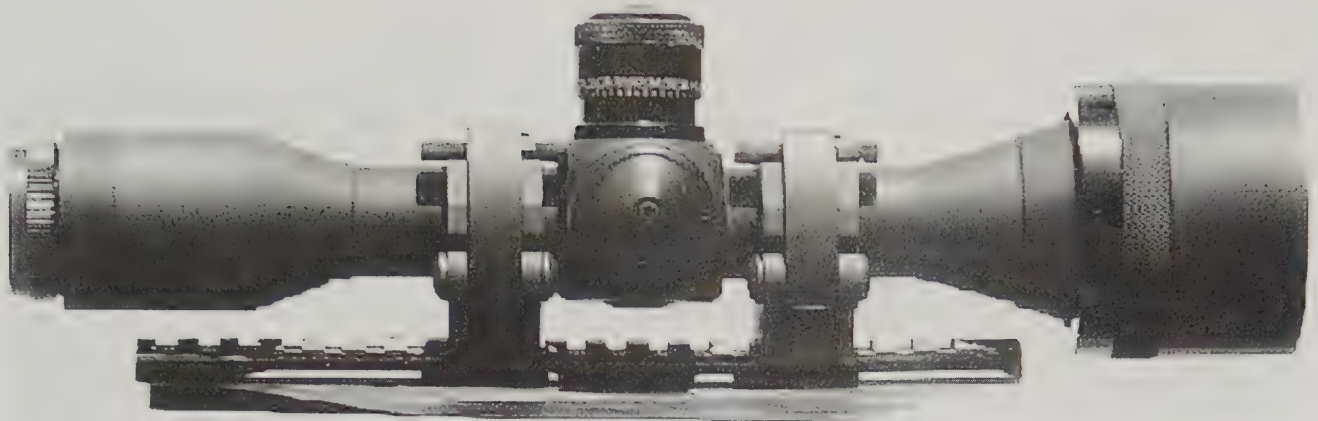
Options include: conversion for left hand operation, larger diameter tubes, larger objectives, interchangeable reticle system, windage and elevation locks, canting indicators, illuminated reticles, titanium or carbon fiber tube construction, built-in laser range finder, and special color finishes.

U.S. Optics SN-2 Ranging Variable

This scope has all of the features of the SN-1. In addition it has variable power in 3.2 – 17x, 3.8 – 22x, or a 5.6 – 28x settings. The manufacturer claims no shift of impact when changing power settings with the reticle in the front plane. With the reticle in the rear focal plane, the shift is less than 1/8th MOA.

U.S. Optics offers the SN-2 in four different standard setups:

- **SN-2-30:** This is the basic model with a 30mm tube. The smaller diameter main tube doesn't allow for a lot of elevation travel. The elevation knob is standard 1/4 MOA clicks or 1/5th or 1/10th available. With the 58mm objective, you can have up to 120 MOA of elevation travel.

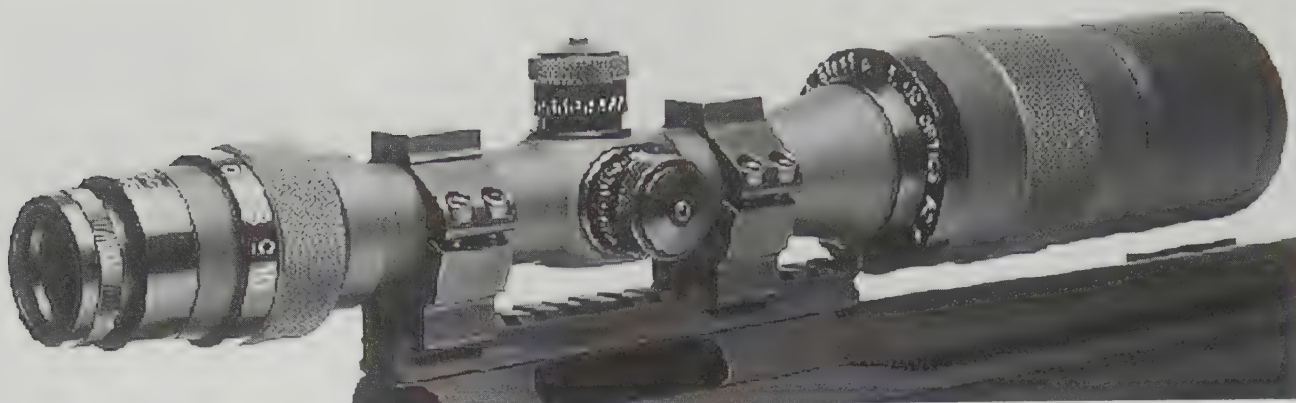


U.S. Optics SN-2 variable power with BDC.

- **SN-2-35:** This scope uses a 35mm main tube diameter. This allows more erector cell travel in the scope. The 35mm tube diameter allows 120 MOA of elevation travel with the 58mm objective without optical distortion (vignetting) caused when the erector cell is “looking” through the edges of the lens because of extreme elevation and windage settings.
- **SN-2-40:** The main tube diameter is 40mm. This allows a proportionately larger erector cell and allows more elevation travel.
- **SN-2-50:** With the 50mm main tube diameter you can have up to 300 MOA elevation travel without using a larger objective lens diameter. The larger tube diameter also contributes to a much stronger construction. Price of this scope without additional options and using ultra-high resolution lenses is \$3,749.00. All options listed under the SN-1 are available on the SN-2 outside of these four basic construction formats.

U.S. Optics SN-3 Series

This scope was designed to fill the gap between the SN-2 and the SN-4 optical sights. It provides a wider field of vision than the SN-2 and has more power than the SN-4. The SN-3 is the variable power version of the SN-6. U.S. Optics claims that the SN-3 combined with their Posa-Slide and Lock mount is the perfect combination for the flattop gas-rifles such as the SR-25 and the AR-10. The standard format SN-3 comes with a 44mm objective lens diameter and a 30mm-tube diameter. Power ranges are available with the following settings:



#1 Knobs of U.S. Optics on the SN-3

- 1.4 – 8X with 44mm objective
- 1.8 – 10X with 44mm objective
- 3.2 – 17X with 58mm objective
- 3.8 – 22X with 58mm objective

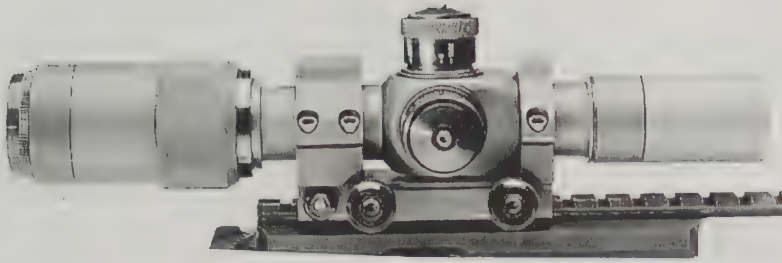
The SN-3 is offered in five basic formats separate from other available options.

- **SN-3 Mark I:** Features a quick-focus eyepiece and extra armor around the turret housing. No lens caps or turret caps are included in this model.
- **SN-3 Mark II:** The Mark II includes lens and turret caps. When the caps are installed, the unit is waterproofed to a depth of 100 feet and shock hardened against damage from a 5-foot drop with a 10-pound rifle. The Mil-Dot reticle is standard. The scope is adaptable for CCTV, infrared night vision and internal laser range finding capabilities. With the 30mm tube, elevation travel is from 160-180 MOA and 180-220 MOA with the 35mm tube.
- **SN-3 Mark III:** All of the features of the Mark I and II. The Mark III has a 35mm tube as standard.
- **SN-3 M-4 Long Range:** Has all of the features of the Mark I and II with a choice of 30, 35, or 40mm-tube diameter. Choice of 1/4, 1/8 or 1/10 MOA click adjustments. A 44mm or 58mm objective is the operator's choice. Rings and mounts are included and a choice of a one-piece bridge mount with screw lock precision rings or a Posa-Slide mount is included in the package.
- **SN-3 Mk V:** The Mark V is a standard M-4 package with digital readouts for windage and elevation. A 1500-yard laser rangefinder is built in.

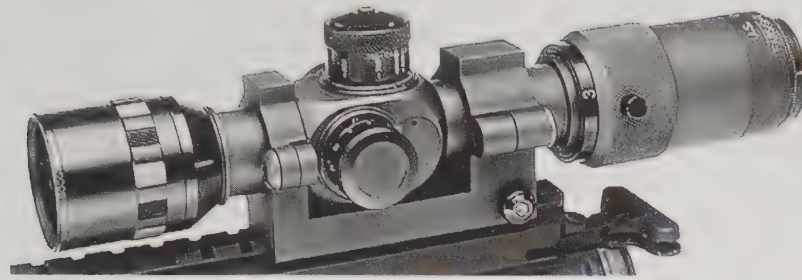


U.S. Optics SN-4 Series

The SN-4 was developed as U.S. Optics' response to the Elcan and ACOG fixed power combat optics. These multi-spectrum optics can be used as an optical sight package that is interchangeable between many light class guns. When it is set up with multiple BDCs, you can change your sight from an M-4 to a SR-25 or AR-10T to a 7.62mm rifle. The ACOG and Elcan scopes do not have diopter adjustment; therefore, shooters



SN-4 with fixed objective lens.



SN-4 with adjustable objective lens.

without 20/20 vision will have a blurred reticle. The SN-4 has adjustable diopter value. The reticle is in the front plane. As the power is dialed up or down, the reticle pattern stays correct on the target. These scopes are directly aimed at the SWAT market and have a good application in the CQB (Close Quarters Battle) arena. With a power range setting of 1-4X and an illuminated reticle (11 power settings) this scope can be used for room clearing and then the higher power can be used while outside a target and during the movement phases of an operation. When using the slide and locking mount an operator can quickly remove the sight and go to his iron sights in less than 3 seconds. He can shove the sight in a pouch or a cargo pocket and continue his job. A

screw-on power doubler can instantly double the power of the system, adding a long-range observation/shooting capability. The SN-4 is offered in four basic packages:

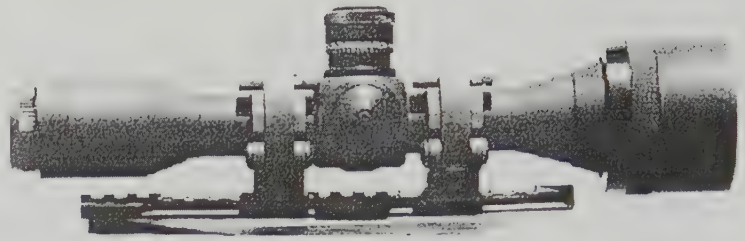
- **SN-4 Mark I Rapid Response:** The rapid response adds to the basic model with a circle-dot ranging and acquisition reticle, BDC and 1/2 MOA adjustments for windage and elevation.
- **SN-4 Mark II Rapid Response:** The scope has an optional 11-position rheostat switch on the left side for an illuminated reticle. The tube diameter is either 30mm or 35mm at the customer's request. All parts of the scope are pre-threaded for caps and covers, but are NOT included.
- **SN-4 Mark III A.N. (Army-Navy) Rapid Response:** This scope has all of the features of the Mark I and Mark II. Included are heavy-duty objective extension caps that include an optical glass lens insert to protect the objective lens. Armored caps for the windage and elevation knobs are also included as are screw-on or Butler Creek flip-up caps for the ocular and objective lens.
- **SN-4 Safari:** This scope has the same features as the Mark II but uses a standard coin slot adjustment for elevation and windage instead of the military type BDC and windage knobs. The knobs are low profile, which keeps them from being damaged in rugged Safari conditions. The 22mm exit pupil in the 1-4X model makes this scope a very fast target acquisition optic. The field of view is very wide (117 feet at 100 yards). An optional 2X doubler can double the power range to 2-8X.

U.S. Optics SN-6 Series

The SN-6 scope is a fixed power optic designed for long range shooting situations. The U.S. Optics #1 knob (1/4 MOA elevation adjustments) is standard but can be ordered with a BDC. All forms of the SN-6 have the 44mm or the 58mm objective diameters available. The power ranges are 10, 17, 22 and 28X. The SN-6 is offered in five major formats:

- **SN-6 Mark I A.N.:** Features include one-piece tube construction from front to rear, a European quick-focus

eyepiece, extra aluminum armor around the eyepiece and objective lens area, and the around the turret area. The reticle can be placed in the front or rear focal plane. Eyepiece, objective, windage and elevation covers are not included in this package.



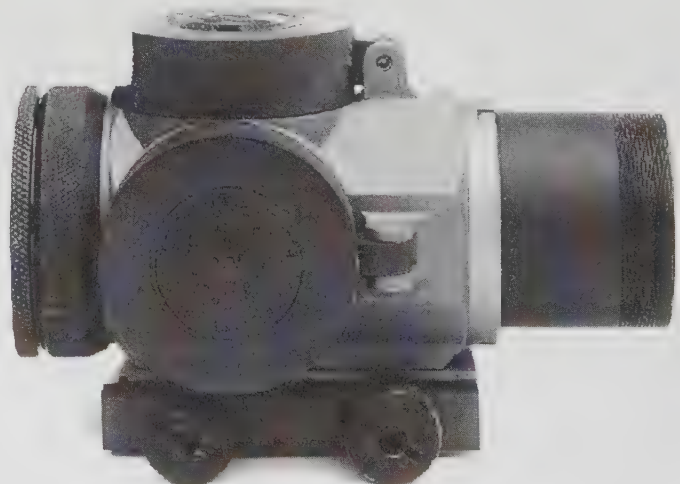
U.S. Optics SN-6 fixed power.

- **SN-6 A.N. Mark II DM (Designated Marksman) Marine Corps:** Same features as the Mark I, but with screw on caps for the elevation and windage knobs, flip-up Butler Creek or screw-on caps for the objective and ocular lenses. The Marine Corps model has a BDC with a Mil Dot reticle pattern for indexing corrections and range finding. BDCs are available for 5.56mm, 7.62mm, .300 Winchester Magnum, and the .338 Lapua Magnum. The optics can be laser-hardened to protect the shooter's eyes and the system is adaptable for CCTV, infrared, and laser range finding. Range of adjustment is 160-180 with the 30mm tube and 180-220 with the 35mm tube.
- **SN-6 EHD (Extra Heavy Duty):** The EHD model has all of the features of the Mark I but with a 35mm-tube diameter. The base and rings are included and are a choice of an integral Picatinny rail mount of 35mm more rugged L&S Mark IV/Picatinny rail setup.
- **SN-6 M-4 LR (Long Range):** This scope includes all of the features of the Mark I and Mark II, plus a choice of a 30mm or 35mm tube. It has an external bubble level, windage and elevation locks, 1/4, 1/8, or 1/10th MOA elevation clicks, and a choice of a 44mm or 58mm objective lens diameter. Ring/base combination is included and is either the Posa-Slide one piece mount or screw lock precision rings with a one piece extended bridge rail mount. The scope comes with a 4-inch sunshade and caps are included for the objective and ocular lenses and the elevation/windage knobs.
- **SN-6 M-4 ASAP (Automatic Systems Analysis Program) A.R. (Auto-Rangefinding):** This scope is the standard M-4 Long Range with digital readouts for windage and elevation. The 1,500 yard laser rangefinder is included. As elevation and windage settings are indexed, they are displayed for the operator to see inside the scope. As the laser range finder sets the range, the micro-circuit contains the trajectory data for the round and displays the elevation and windage data needed to index for the shot. Cost of the ASAP/Laser Rangefinder system is \$1,500.00 in addition to the cost of the scope. Cost of digital readouts alone is \$550.00.

U.S. Optics SN-8 Modular Series

The SN-8 is the world's first modular approach to telescopic rifle sight construction. While a complete system is expensive, the quality and the opportunity to have a "briefcase" scope system is unsurpassable. Here are some of the features:

- **SN-2-50:** Fixed powers from 1X to 40X are available, as are 4:1 zoom ratio variable power eye pieces.
- CCTV, Infrared and passive night vision systems available.
- Resolution at 100mm/line pair.



U.S. Optics SN-8 modular.

- Objective sizes at 35mm, 44mm, 58mm, 72mm, 88mm, and 100mm.
- U.S. #1 elevation knob is standard (1/4 MOA clicks) with 150 MOA of travel available with options for other values.
- Interchangeable reticle patterns.

The SN-8 can be ordered with many possible combinations. The #1 knob is the standard (1/4 MOA clicks) but the BDC or ultra low profile knobs can be ordered and are operator interchangeable. The system comes in three different components, all of which are interchangeable within themselves. The component systems are:

- **The Scope Body.** The body is offered in both left- and right-hand versions. It can be ordered alone or with four different objective assemblies as part of a package. Stated price range is from \$595.00 for the basic body to \$2,300.00 with the body and an ultra-high resolution 40X objective.
 1. SN-8 right- or left-hand version, with no objectives or eyepieces.
 2. SN-8 with a 4X objective.
 3. SN-8 with a 10X objective.
 4. SN-8 with a 20X objective.
 5. SN-8 with a 40X objective.
- **Objective Lens Assemblies.** These objective assemblies can be ordered separate from the scope body. Assemblies are available with high resolution or ultra-high resolution lenses. Price range from \$245.00 to \$1,600.00.
 1. 1X objective.
 2. 4X objective.
 3. 10X objective.
 4. 20X objective.
 5. 40X objective.
- **Eyepieces.** Fixed and variable power eyepieces in both high resolution and ultra-high-resolution models are available. Price range for the fixed power versions are from \$235.00 to \$695.00. The variable power eyepieces are at a 4:1 zoom ratio with 2-4-inch eye relief.
 1. 2-inch Eye Relief eyepiece.
 2. 3-inch Eye Relief eyepiece.
 3. 4-inch Eye Relief eyepiece.
 4. 5-inch Eye Relief eyepiece.

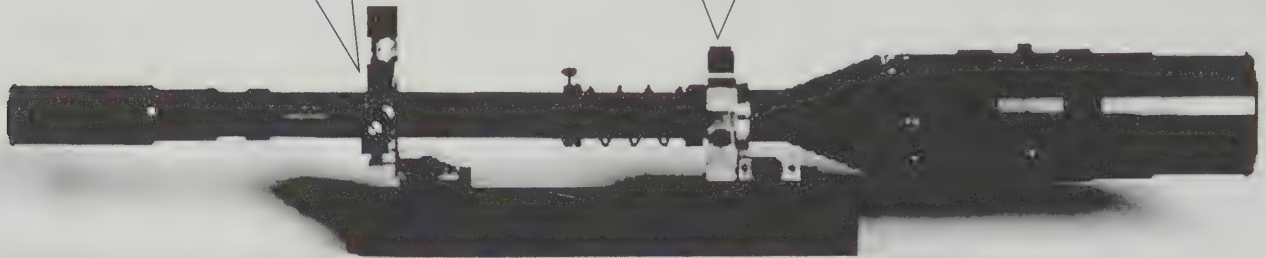
The true beauty of the SN-8 system is its ability to be customized for each mission. An operator may have the 40X objective assembly with a long relief eyepiece for observation of the target area and detecting targets. When necessary he can switch his objective lens assembly to a lower power unit. He may want to switch the eyepiece from a fixed power setup to a 4:1 variable power unit. Depending on the mission and the gun used, a BDC may work better than an elevation knob with 1/4 MOA clicks. The combinations are not endless, but it is safe to say that any shooting situation can be covered with a combination of the above systems. The SN-8 package makes an excellent stand-alone observation scope.

Externally adjusted optical sights

Many of the scopes out, including the other scopes in the U.S. Optics line, are variations on a single theme. The scope body is a housing for a smaller telescope that is inside this outer tube. This internal scope

The elevation and windage knobs make physical contact with the scope tube, moving the entire scope up and down in the rear, changing the angle more precisely than the internally adjusted scopes.

The forward ring provides tension against three sides of the scope. This repeatedly centers the scope in the ring shot after shot. The spring is there to return the scope to battery as it moves under recoil. Many competition shooters remove this spring and do the process by hand. This ensures it is done fully each time.



known as the “erector cell” is what moves up and down on an angle when you move the elevation and windage knobs on the scope. This is true for BDC as well as 1/4 MOA click-type knobs. The lenses in these erector cells are about .500 inches in a scope tube with a 1 inch diameter. This means that there is poor performance in the erectors, and when higher magnification is pumped through the lens the system can’t handle it. With a scope of relatively small diameter—1 inch or 30mm—and you have a lot of travel in the elevation knob, a kind of distortion called vignetting is certain to occur. The result, in lay terms, is that you aren’t aiming at what you are looking at. This means errors in point of impact versus point of aim.

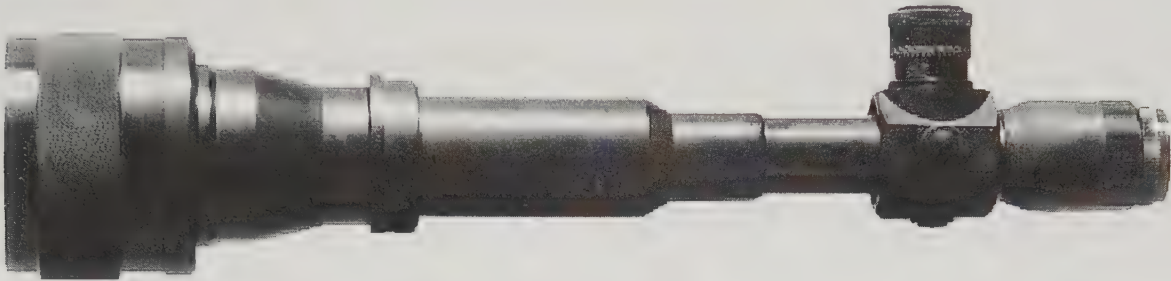
Why have a huge 58mm objective lens when the image is pumped through a little tiny .500” lens (those are the big ones)? Another problem exists when you have dialed in an extreme amount of elevation and you are not “looking” through center of the objective lens. The farther away from the center of the lens you get, the more optical distortion there is. This distortion is called vignetting. Solutions are available. One is to use the larger diameter tubes as offered on the U.S. Optics scopes. Large diameter means larger erector cells and almost no vignetting when at the extreme ranges of elevation travel. The other option to cure this problem is to use externally adjusted scopes.

In Chapter 5 you will read about base angles and the various reasons for machining angles into bases. It is not just done to reach out farther with the elevation drum. One of the main reasons to machine an angle is so that the extreme range elevation settings are roughly in the center of the elevation travel of the scope. For example with the Leupold & Stevens Mark IV, M-1; when you have a 75 MOA base and you are shooting at 1,500 meters, you are almost dead center in the lenses, no vignetting. At 1,500 meters, the elevation setting is 78.50 MOA with the Mark 211, Mod-0 round in .50 caliber. The center of the elevation and lenses on the Mark IV, M-1 16X is 75 MOA. Can’t ask for better than that.

Externally adjusted scopes are commonly used on competition benchrest and long-range rifles; these scopes have adjustments that move the entire scope up and down or left and right. The knobs frequently resemble micrometer knobs more than they do scope knobs. The most commonly known of this type is the Unertl competition telescopic sight. Externally adjusted scopes are fantastic for their ability to make precise inputs. The way that this works is that the knobs on the outside of the rear ring make physical contact with the actual scope body. As the knob is turned the gearing literally moves the entire scope tube up and down in the rear of the scope. The forward ring bears pressure with spring loaded pistons and acts as sort of a hinge allowing the scope to move freely. With this little explanation out of the way, let’s take a look at U.S. Optics’ externally adjusted long range scope.

U.S. Optics SN-9 ASA-ERTS (*Advanced State of the Art, Extreme Range Telescopic Sight*)

Due to the extreme elevation settings required in some extreme range shooting solutions, an externally adjusted scope (EAS) may be the best way to go. For some reason there seems to be resistance to the realities that exist between normal sniping ranges (out to 700 or 900 meters) and the really long stuff (1,500+ meters). Due to very limited locations where one can shoot this far, and the equipment needed to do it, very very few shooters have had the opportunity to work the problems out with any degree of true scientific approach. The SN-9 is the state-of-the-art approach to vignetting and high precision with ultra-high resolution optics. There is no limitation on elevation or problems caused by optical distortion or bad light coming into an erector cell at an extreme angle. The SN-9 uses armored elevation and windage turrets. These scopes have adjustable objectives and European quick-focus eyepieces.



U.S. Optics SN-9 ASA-ERTS Externally Adjusted Sight.

For operators that are worried about the damage that this system may sustain in movement, remove the scope. These systems repeat zero from the removal and replacement process than the internally adjusted scopes do. Part of the reason is the spring loaded ring systems on the scopes. With the SN-9, you are always looking through the center of the lenses because the total scope moves up and down in the rear. The SN-9 is offered in Lensmatic and Prismatic systems and they are set up as follows:

- **Lensmatic Systems – Fixed Power Models**
 - 15X with 58mm Objective
 - 20X with 58mm Objective
 - 25X with 58mm Objective
 - 30X with 80mm Objective
 - 35X with 80mm Objective
- **Lensmatic Systems – Variable Power Models**
 - 3 – 15X with 58mm Objective
 - 4 – 20X with 58mm Objective
 - 5 – 25 X with 58mm Objective
 - 6 – 30X with 80mm Objective
 - 7 – 35X with 80mm Objective

- **Prismatic Systems –**
All Fixed Power Models
 12X with 58mm Objective
 18X with 58mm Objective
 24X with 58mm Objective
 32X with 80mm Objective

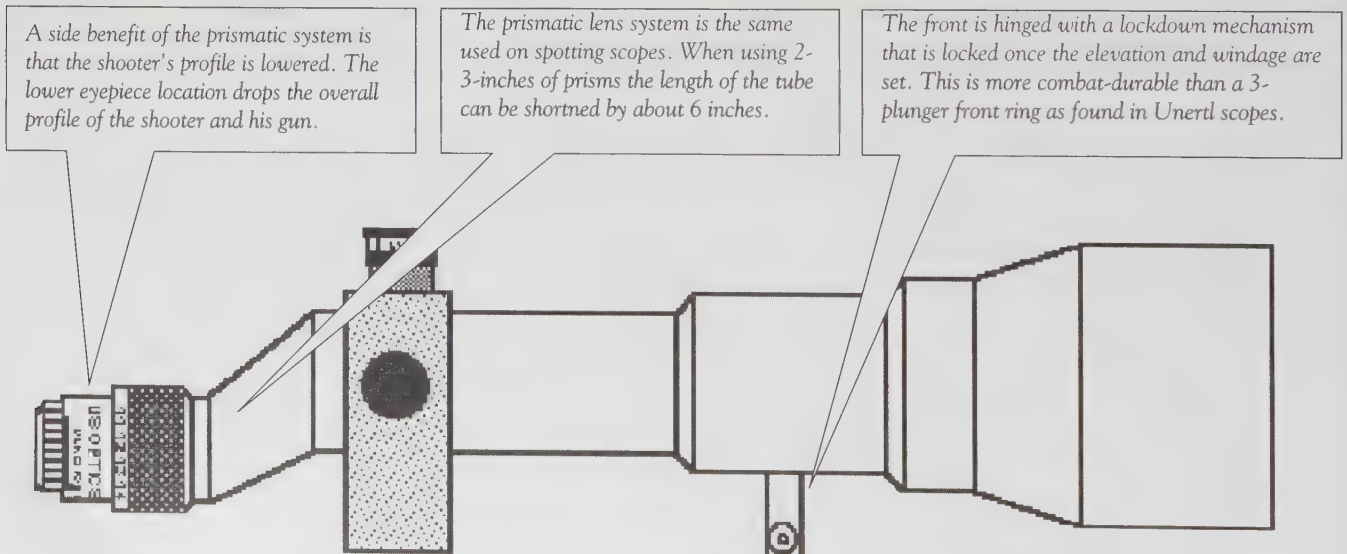
U.S. Optics Advanced Concept Prismatic Externally Adjusted Scope

Dr. John Williams, president of U.S. Optics, is committed to making the best optical sights on the market and has redefined the cutting edge of extreme range sniper grade optics. The SN-9 is already one of the top sniper-grade optics systems. It is impossible to argue with an adjustment system that is superior in every way to other methods of adjustment. U.S. Optics is developing an even more advanced model of an externally adjusted scope.

The new scope is a prismatic design. For the military guys, think of an M-49 spotting scope with a reticle in it, and external adjustments for elevation and windage. Mount that on a gun, step up the power, and make it about 3 times more clear with stepped up light transmission. That's a long-range optical sight. As with any other externally adjusted scope, those adjusting mechanisms will require a bit more care than your average SN-6 with its armored caps. The reality is that the extreme range sniping mission is not within the capability of average school trained snipers. That's not their intent. Current military schools train apprentice level entry into sniping. As you will read in Chapter 4, "Introduction to the Training Environment," not just every light gun shooter can pick up a heavy gun and make it work. That chapter explains the dynamics involved.

The new advanced concept scope uses a lot of features that make it look like a spotting scope setting on top of a rifle. The first thing that catches the eye is the prismatic section at the rear of the scope. By using 2-3-inch prisms to compress the incoming light, you can shorten the length of the main tube by about 6 inches. This cuts down on weight and bulk.

There are two more good reasons to have the eyepiece lowered. First, you lower the shooter's profile to an enemy observer. It doesn't look like a lot of difference, but in the terms of silhouetting and shadows (two target indicators), the difference is significant. Second, many optical sights are higher up off the gun (take a close look at the Warlock .50-caliber rifle on page 43. The shooter's face would either be off the stock, or an adjustable cheekpiece would have to rise up high to get the shooter's eye behind the eyepiece. This also has





Mitchell Optics Competition .50-caliber scope.

the effect of lowering the center of the bore out of that “shooter’s pocket” on the shoulder. This causes the muzzle to make a more vertical jump because of bore misalignment on the shoulder. Ideally, a gun should not need an adjustable cheekpiece. Some rifles have adjustable buttplate assemblies that allow the buttplate to slide up or down. This gets a good purchase on the shoulder, however, the bore is still below where it should be to reduce muzzle jump.

The front of this scope has a special hinging system instead of the traditional 3-plunger ring method used in externally adjusted scopes. This is much more combat-durable and has fewer moving parts. The rear ring contains the adjusting knobs for windage and elevation. The bearing surfaces where the knobs meet the scope body allow for adjustments that are more precise. On an internally adjusted scope, the large flat surfaces where the shaft foot meets the erector cell cause a change in the angle of incidence between those two surfaces. As the knob is moved up or down, the actual value of each click changes as the angle of incidence changes. At extreme elevation settings, this value is significant. A MOA is not longer an actual MOA.

There are locks on the elevation and windage knobs and on the front hinge so that the system can be locked down solid when the settings are in place. This scope is NOT designed to move in battery as is the scope above. The fact that there is no internal erector cell means that larger and better seated lenses can be used. The tube housing itself can be more massive to resist damage. As was stated earlier, it’s a spotting scope on top of a rifle. The options have not all been worked out, but it is safe to assume that this system can be set up with CCTV, infrared and passive night vision tubes as well as laser range finders and digital internal displays.

This is just one of the projects under way at U.S. Optics. The company is dedicated to producing the finest military, police, and competition grade optics in the world. In my opinion, they are there now.

Mitchell Optics External Adjustment .50-Caliber Rifle Scope

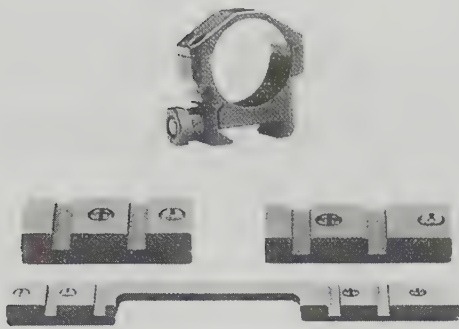
These scopes are designed for competition .50 caliber rifles commonly found in the Fifty Caliber Shooter’s Association (FCSA). This scope is of the classic Unertl competition design. While it is not durable enough for combat applications, it may be, in the hands of the right operator. The USMC used externally adjusted scopes for years with good results. They did have their mechanical problems, however.

The list of optics capable of performing on heavy-class rifles is small. Certainly there are other scopes out there that may do the mission, but these are the proven systems to date. With the exception of the Mitchell Optics scope, they are built to meet or exceed any applying Military Specification, have been tested or are in use by military forces in the United States and overseas.

OPTICAL SIGHT MOUNTING SYSTEMS

Leupold & Stevens

The Leupold & Stevens Mark IV rings and base sets have been the standard used on sniper weapons systems

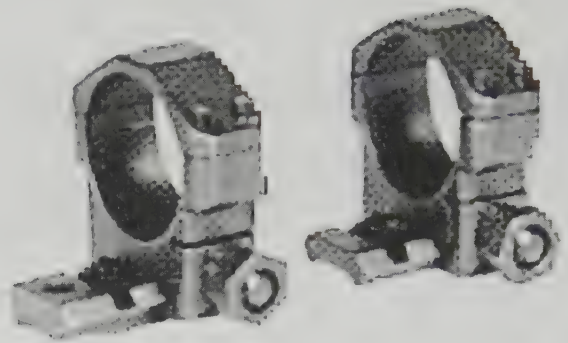


Leupold & Stevens Mark IV rings and base sets.

since their creation in the early 1980s. They are the most copied design of ring/base set on the market. These sets have a fine reputation for having an ability to repeat zero when removing and re-installing the scope on the gun. The bearing surfaces on the base are machined on a 45 degree angle, with corresponding angles on the claws of the ring. Tension is provided with a 1/2-inch nut torqued to 65 in. pounds. It is suggested that a minimum screw size of 8-40 be used to mount the base to the receiver. Many heavy-gun builders use even larger screws to mount them.

Badger Ordnance

Badger Ordnance makes a ring that is wider and more precisely machined than the Leupold & Stevens Mark IV ring. The Max-50 ring is a full inch wide, giving a huge bearing surface. Reducers are available to convert from 30mm to a 1-inch ring. Badger also offers a standard width ring that works just as well on all classes of guns. The rings are machined in matching pairs and are serial numbered. Badger provides an ultra-high (1.37 inches) ring set that works well on the SR-25 and AR-10 rifles as well as 5.56mm AR type guns. This company also machines a Picatinny rail scope base that is machined to an angle of 20 minutes. This provides the extra range needed to push "a little" farther, but does not come close to setting up a Leupold & Stevens Mark IV, M-1 to a Parallel Bore Zero method. The Badger and Leupold Mark IV rings and bases are all steel construction. This has minimal expansion and contraction from heat and cold temperature changes. This is important to military special operations guns.



Badger Ordnance Max-50 rings.



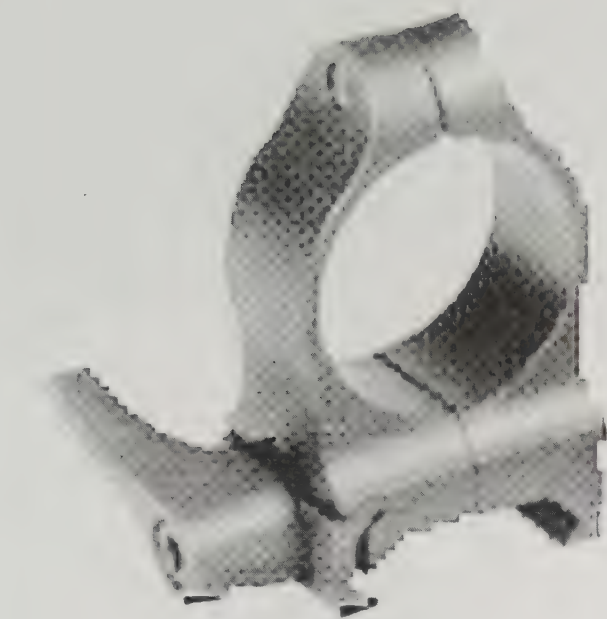
MGW rings and base.

MGW

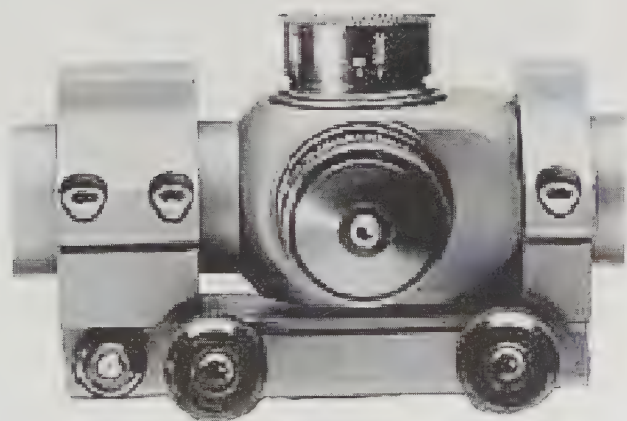
MGW produces their version of the Mark IV rings and bases. The profile is slightly different than the Leupold rings, but they are pretty much the same concept. They are machined out of 4140 steel. The rings are available for 1-inch and 30mm diameter scope tubes and come in standard (.375 from top of base to bottom of the ring hole) and extra high (.750-inch tall) heights.

Warne

Warne has been a builder of a much more economical type of ring for a few years. Recently they added the Maxima rings and bases. The Maxima design is made to interface with Picatinny bases or their own Maxima two-piece bases. The rings are cut in steel, and bases are available in steel or aluminum. They are available in 1-inch or 30mm diameters. These rings do not use a nut requiring a specific torque value. They use a simple locking lever that once it is locked down, can be lifted and rotated to whatever position the operator desires. The rings are vertically split. This is somewhat better than horizontally split rings (in Warne's design) in that when tightening the horizontally split rings, it is easy to cause the scope to cant while tightening. While there has been little testing in the ability of these rings to grip a scope on a .50-caliber rifle, they have been used on medium class guns like a .338 Lapua without a muzzle brake and many .300 Magnums. Both of these calibers recoil heavier than the .50 caliber guns and require more tension to hold the scope in place.



Warne Maxima rings.



U.S. Optics Posa-Slide and Lock mount.

locking bolt that is squeezed when the operator loosens the tension bolts on the mount. This system has excellent zero repeatability. If there is a problem, it is that the mount is made out of aluminum. The material certainly is strong enough to do the job, but the coefficient of expansion from the extreme temperature changes that military operations encounter could cause problems with the zero. The surface finish is precision hard anodized in matte black, gray, green, and stainless. The mount weighs only 8 ounces and is machined out of 6061-T6 aircraft grade aluminum. Recoil surfaces on the base are machined out of steel.

U.S. Optics Technologies***U.S. Optics Technologies Mounting Systems***

The Posa-Slide and Lock mount is designed to allow an operator to rapidly move a scope forward or rear on the base. Not shown in the pictures is a

U.S. Optics Lever Lock Rings

These rings are a different concept from the traditional ring-to-base interface that is usually used. Long

ago the U.S.M.C. decided that rings being taken off and reinstalled on the base didn't mean a good return to zero. The U.S.M.C. decided to weld the rings to the base. Very tough system. The Lever Lock ring is roughly the same concept. There is no welding involved, but the rings are intended to stay on the base. They are designed to interface with the standard Picatinny base. Once you put them on, you never take the rings off. If you have to remove the scope, you open up the ring by unlocking the locking lever and lifting the scope out of the ring set. The rings are machined out of 6061-T6 on CNC mills. The tolerance is set at $+.000$ -inch to $-.0002$ -inch on the inside of the ring. This ensures perfect alignment and no bogus scope tension from misaligned rings. The rings can be ordered with a clamping foot on both sides of the ring body. This allows for a course windage adjustment to get the windage knob on a scope centered perfectly for a mechanical zero. Lever lock rings are available in scope diameters of 30, 35, 40, and 50mm.

U.S. Optics Screw Lock Rings

The screw-lock rings are a 3-piece unit that has a hinged top ring half that tensions the scope tube with two screws. The base clamp is a free floating clamp that is tensioned with two 10-24 tpi hexcap screws. The clamps only grip the base with tension and there is no cross bolt as in the Mark IV design. A recoil plate is screwed to the front of the ring that can be adjusted up or down to interface a recoil cross slot if desired. The rings can be ordered to handle diameters of 30, 35 and 40mm scope tubes. Heights vary from 1.200-inches (measured from the top of the base to the center of the ring) to 1.750 inches.

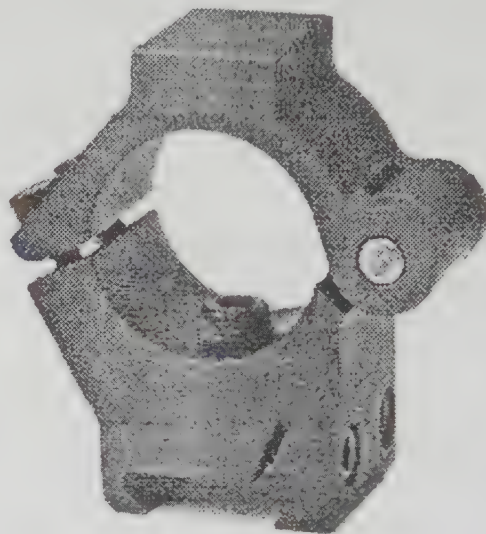
It is important to know that these rings—as are the Mark IV, MGW, and Badger rings—are designed to interface with the Picatinny rail design. This is not the same as the Weaver design. While the appearance may be roughly the same, the dimensions of the Weaver rail are different. Bases manufactured by Leupold & Stevens, Badger, MGW, and Atuagua Arms are manufactured to the same specifications as the Picatinny rail.

NIGHT VISION SYSTEMS FOR HARD-TARGET INTERDICTION

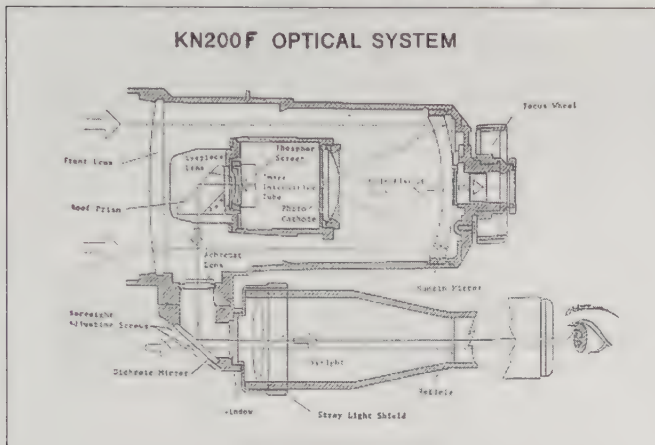
Night vision sights have long been a shortfall in military sniping. The AN/PVS-10 is just now going online in many special operations units. The Special Forces group that the author left still had no night vision capability for their sniper weapons (each SF A-team only had 7 sets of AN/PVS-7s at last check, which is pretty bad). In fact within Army Special Forces the entire night vision weapons sight program is pretty



U.S. Optics Lever Lock ring system.



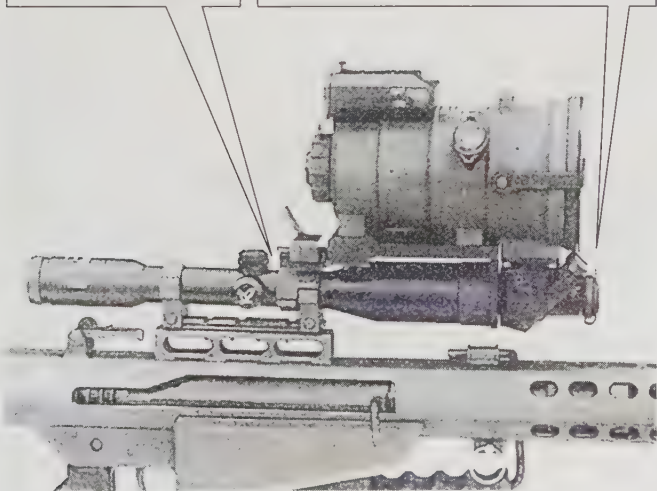
Screw-lock rings.



Daisy M600 suppressed with SIMRAD NV sight.

The SIMRAD mount is a dovetail mount that interfaces the front ring and still retains the top cap.

The boresighting adjustments realign the reflecting mirrors to compensate for the effect of attaching this weight to the day scope. Errors as much as 6 MOA have occurred from attaching the sight.



Early model KN200 with bore sighting adjustment knobs on the front of the SIMRAD.

lacking. With the advent of the AN/PVS-15, the M-4 finally provides a decent night vision sight for the team's individual weapons.

In the United States, the core of the night vision sight, the intensifier tube is only built by two companies: ITT and Litton. All manufacturers of the night vision sights, scopes, and viewers use tubes made by these two companies. The intensifier tube is the component that sits inside of the sight housing that gathers what light is available and intensifies that image. It is then either projected to the eye through a series of lenses (M-995 style) or is reflected through a set of mirrors and then into the front of the day optic (SIMRAD style). The first night scope we are going to take a look at is a system that reflects the image through mirrors and into a day scope.

SIMRAD KN200 and KN250 sights

The SIMRAD KN200 and KN250 sights are the first of the type that reflect the image into the day scope. This allows the operator to use all of his standard and known data without changing the total sight system. There are three versions of this scope. The generation I KN200F and generation II KN200F, with the boresighter adjustment on the front of the night scope. A special dovetail mount is attached to the day scope's front ring. The SIMRAD slides onto this mount and a coupling goes into the front of the day scope. The generation III model was the KN250. This sight uses a generation II night-vision tube and is packaged in a much smaller housing. All SIMRAD systems either use or are adapted to use AA batteries. These scopes were designed for use with lower power. They work very well with 6X optics. They lose a good deal of clarity on 10X systems and are totally unusable on 16X systems. Infrared illumination does help the situation, but not much. The Army only recommends the KN250 for use on .50-caliber rifles. Technical details on the sight and its method of zero are in Chapter 5.

Night Augmented Day Scope 850 Series

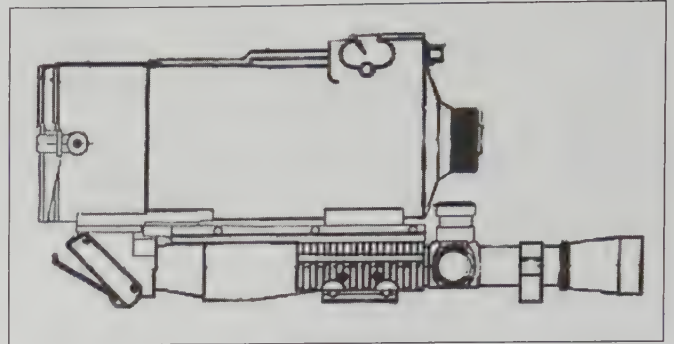
This scope is another version of the SIMRAD concept. This system was extensively tested by the military, but was not generally adopted by them for special operations units. Knight's Armament made a different version of the mount, but the concept of

mounting was still the same. There is no boresighting adjustment on these scopes. Both the SIMRAD and the NADS (night augmented day scope) systems claimed to have no affect on the zero of the gun. However, both systems had zero impact changes ranging from none to 2.5 MOA for the NADS and as much as 6.0 MOA for the SIMRAD system.

Litton Industries AN/PVS-10 Day/Night Vision Scope

The AN/PVS-10 is the very first dedicated sniper night vision scope. As of this writing, there is only one version of the scope in the field. This is the 8.5X version intended for the M-24 or other .308 caliber sniper weapons systems. The version that is being developed for the heavy class guns is a 12X magnification. The night sight has a generation III or better intensifier tube with a claimed resolution of better than 50 line pair per millimeter. Details on this optic and its zeroing procedure are in Chapter 5.

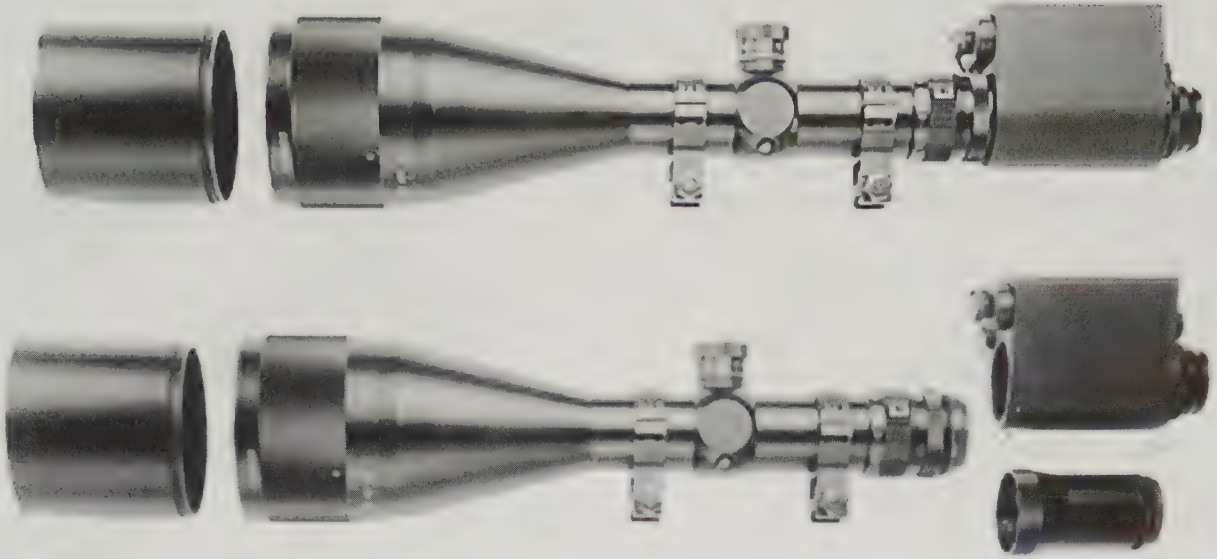
These next night vision scopes represent a new method of using night vision packages to enhance a day scope. Whereas the SIMRAD and the NADS sit on top of the day scope (piggyback optics), these new



Above and top: NADS 850 attached to an SR-25 with Knight's Armament mount kit.



Top and right: Litton Industries' AN/PVS-10 day/night sniper scope. 8.5X version for the M-24 and a 12X version for heavy guns.



Vision Master by Seiler Instrument.

scopes attach to the back of the scope or are integrated directly into the day scope. Micro-circuit technology has allowed the intensifier tubes to be made even smaller and with the best level of performance available (generation III). There is a fantastic weight savings over systems that are the state of the art such as the AN/PVS-10. The generation III night vision package is about the same size as a package of cigarettes. The major advantage of these systems is that virtually all of the features of the high quality day optic are used. The best lenses, elevation and windage systems—everything, remains the same. All that is added is a little box (visually) to the top of the scope tube. A couple of these scopes have systems that are added on to the back of the ocular lens. More weapons manufacturers are offering night vision sights with their rifles, but for some reason claim that they are for law enforcement only (company policy, not law). Remington and H&S Precision are two major manufacturers of sniper rifles (but no heavy-class guns) that are offering generation III night vision packages as part of their sniper weapons systems.

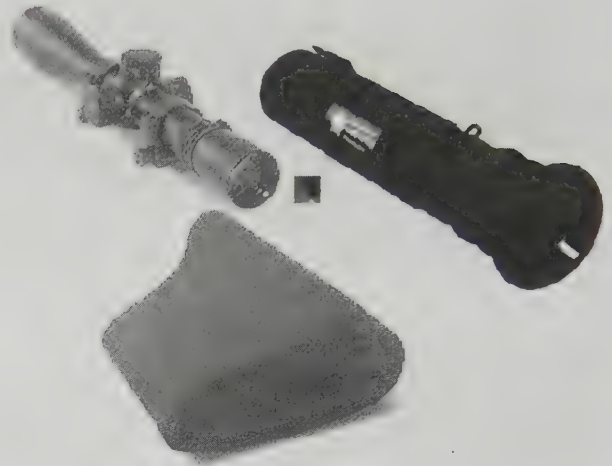
The Vision Master by Seiler Instrument and McBros Rifle Company

This scope is one of the few that is built in a larger than 30mm tube diameter format. The main tube on this scope is 40mm with an objective lens of 80mm. They are variable power from 6-16X and have 60 MOA available on the knob using 1/4 MOA clicks. The night vision system is powered by two AA batteries. The day scope weighs 66 ounces and with the night vision device attached the weight is 83 ounces. Seiler Instrument offers a 2.5-10X scope with a 56mm objective also. The elevation system has 50 MOA of travel and is graduated in 1/4 MOA clicks. Tube diameter is 30mm. The system has the following intensifier tubes available:

- 64 line pair/millimeter generation III
- 56 line pair/millimeter generation III
- Standard generation III
- Generation II+

Remington Night Vision

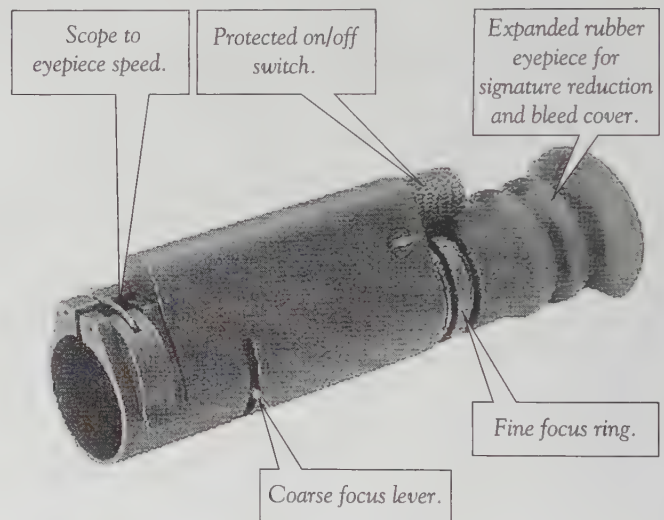
This is a peculiar system. As you can see, the night vision package is rather long. They provide an extension for the stock so you don't have to remove your head and move it back 5 inches. The problem is that this blows your length of pull to pieces. The system attaches to the ocular lens, which is quick and painless. A better mounting option though would be to make an extended base with a long reaching sub-base and eliminate the need for that stock extension. Resolution is 38 line pair/mm for the A model and 51 line pair/mm for the B model. Weight is under 2 pounds with an average battery life span of 45 hours of continuous operation with AAA batteries. Because of the design of this system, it can be used as a monocular for low light observation.



Remington Model RB9712 NVD.

ITT Night Vision Devices

From the leading manufacturer of the intensifier tubes that are on most of the NVDs (night vision devices) today comes an add-on light amplification module. This particular system is offered by H&S Precision of Rapid City, South Dakota. Using the same detaching method as in the Remington system, an operator has the possibility of switching with great speed when necessary and without a reported change in zero. This system has a slightly shorter reach to the eye. The length of pull is still affected because of the long reach of the night scope. By using a mount like the Posi-Lock and Slide by U.S. Optics an operator could push his system farther forward and cut down the "crunch" caused by the rear reaching system. Generation III and better intensifier tubes are available options.

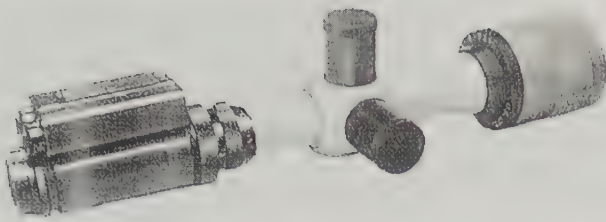


U.S. Optics SN-3 NV (Night Vision)

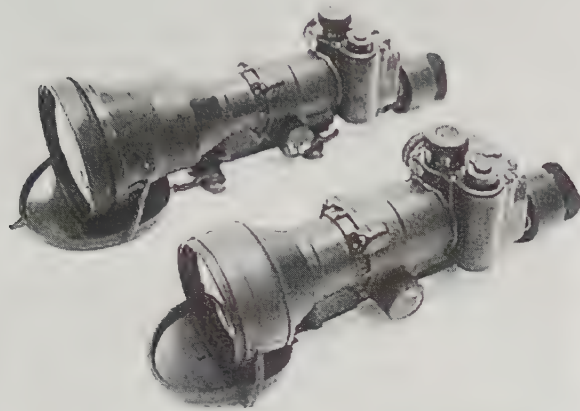
U.S. Optics builds the ocular end system with the ITT night vision intensifier tube. This system is also very similar to the Remington and H&S Precision offered products. The big gain with the U.S. Optics system is that the lenses in the day scope are high or ultra-high (100 line pair/mm) resolution. This means that the resolution isn't degraded by lower quality lenses used in other scopes. When these two products are combined, you have a potent combination. The base day optic is the SN-3. 1/4 MOA clicks for elevation are standard with up to 300 MOA possible



ITT night vision add-on system.



Model SN-3NV.



Litton M-995 Night Ranger.

when using a 40mm tube diameter. The European Quick-Focus diopter adjustment system is retained on the NVD. All generations of night vision are available with the generation III tube having a resolution of 64 line pair/mm. The Mil Dot reticle is illuminated and is standard in the front focal plane. There are two models of the SN-3NV offered:

- **SN-3NV Mark I:** This model uses the standard 30mm tube diameter, extra armor in the eyepiece, objective lens, and the turret housing area. The scope is offered in two variable power models: 1.8-10X with a 58mm objective and a 3.2-17X with a 58mm objective.
- **SN-3NV Mark II:** This scope uses a 40mm tube construction with additional armor in the eyepiece, objective lens and turret housing area. The power setups include a 1.8-10X and a 3.2-17X, both with 80mm objectives.
- **Total System Options include:** Windage and elevation locks on the knobs, external canting indicator, military knobs with rubber armored dust covers, and various sunshades, laser shielding and angular ray deflection.

NIGHT OBSERVATION PLATFORMS

Night observation systems are simply gun sights that are used for observing the battlefield for targets or pure surveillance. The systems selected for this chapter are either some of the very best that the author has used or they are the most common systems available in the military and to the public without a heavy cost output. Stand-alone observation platforms are desired because the specialized night sights that are coming into use (those mentioned on the previous pages) are going to be attached to weapons systems.

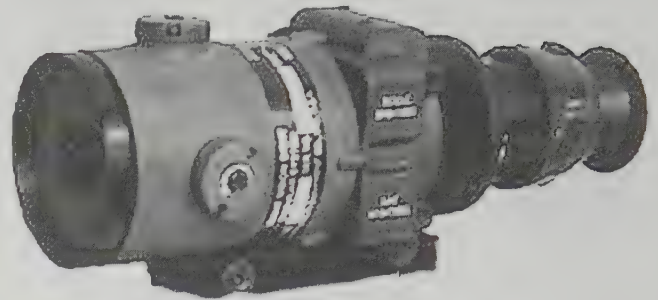
Litton M-995 Night Ranger

The Litton M-995 Night Ranger is one of the most outstanding weapons sights in the military today. It is not a good weapons sight for sniper rifles because it is affixed with a BDC for 5.56mm only. The resolution is high enough for long range observation work. The picture of the M-4 with a M-995 is set up with a long-range laser pointer. The weapon is used as a security or team leaders weapon in which he can use the IR laser to designate particular targets for immediate engagement or as inter-team communications via Morse code. The system operates on lithium batteries and has excellent battery life. The mounting will attach to any Picatinny rail system and is quite durable. As a weapons sight for security weapons, it is excellent. A red, inverted "V" aiming point is used to index a target.

AN/PVS-4

The AN/PVS-4 is an old system that has been used for a long time. The sight was designed for medium-class machine guns such as the M-60. It has been adapted for use on many other weapons systems, including in a very limited number, the M-24. Special mounts were made by Brookfield Precision to mount the PVS-4 to the Mark IV base on the M-24. This created a couple of problems. The sight never was strong enough to handle the punch recoil of bolt action rifles. The mount was also only single point. It interfaced the base on only one cross slot with one 1/2-inch locking nut. This set up a pretty vicious whipping action as the sight was not balanced over the base well. The result was fast and furious failure of the PVS-4.

A few companies have picked up the rights to build these sights and they have been slowly improved with newer generation intensifier tubes. Currently, they can be had with generation III tubes and are doing quite well as observation platforms. As a sight for sniper weapons, they still are not quite good enough. The sight is big, bulky and heavy.



AN/PVS-4.



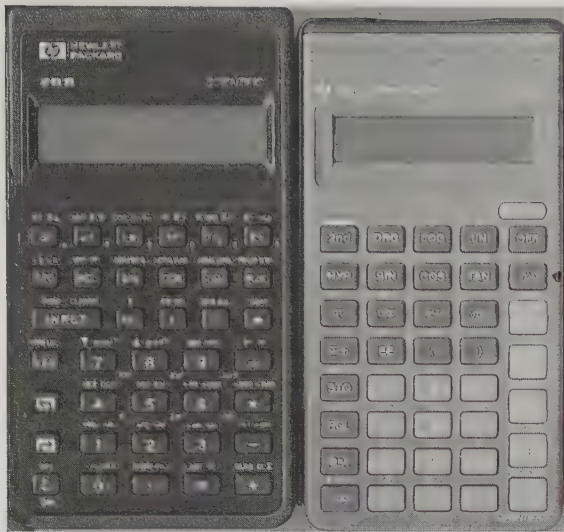
AN/PVS-5.

AN/PVS-5 Night Vision Sight for Crew Served Weapons

This early model sight was first built with generation I tubes. Its intended purpose was for crew-served weapons, more specifically the .50-caliber machine gun. The system is big and very durable. When these were upgraded generation II, their resolution was quite good. The AN/PVS-5 makes a good observation platform when nothing else is available. A couple of these were modified to go on .50-caliber rifles. The big problem was that they made the gun very top-heavy. A much wider bipod footprint and artificial support under the tail of the gun was absolutely necessary to shoot the system. There is no elevation and windage input knobs on the PVS-5. The Point Blank Zero or Reverse Image Zero engagement method must be used with the PVS-4 and PVS-5 to use them on heavy sniper rifles. The PVS-5 was upgraded by some private companies to generation III tubes, mostly for the export market. With generation III intensifiers, these scopes make an excellent long-range night observation platform for static positions or surveillance. For HTI missions, with the already increased weight package, the PVS-4 and 5 systems are just too big, heavy, and single-purposed to be considered, unless that is all you can get.

SUPPORTING TECHNOLOGY FOR HTI OPERATIONS

This section on supporting technology presents some, but not all of additional equipment options needed for the HTI and extreme range sniper mission. These are systems and pieces that have actually been used and are proven. Because of off-the-shelf procurement authorization, not all of these have undergone extensive mil-spec testing. They all did the job however.



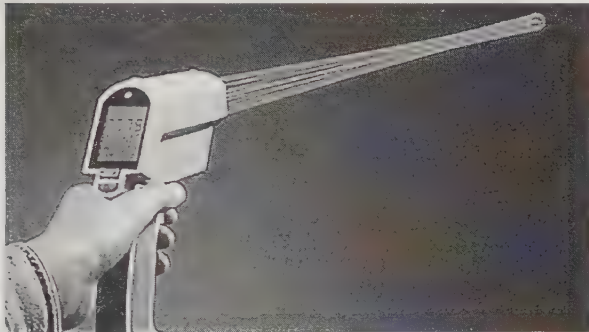
Hewlett-Packard 20S scientific calculator.

Scientific Calculators

Clearly, there are tons of scientific calculators on the market today. These two, the Hewlett-Packard HP20S and the Texas Instruments TI-30X are two calculators that are reasonably priced (under \$35.00) and are very durable. The author has had a HP20S for 5 years and has changed the batteries once in that time. The calculator has been left in the rain, dropped and had a 1-inch square steel block from a milling machine dropped on its face. It kept on working. Because of their logic methods, the two calculators have very similar answers after a 22 or more step calculation. Believe it or not, they don't always do that. Many times, it depends on how the operator sets up the calculator. As you will see in Chapter 6, having students with different types of calculators will drive an instructor crazy. Definitely unadvised are Sharp and Casio calculators.

Meteorological Instruments

These are the instruments used to measure air temperature, barometric pressure and the temperature of the ammunition. The handheld instrument on the left is a portable weather station that tracks the barometric pressure and air temperature and is programmable to store the data in different formats, such as highs and lows over a period of time. The watches are from Casio (Triple Sensor). They also track the barometric temperature, altitude and air temperature. Put one in the ammo container and you can determine your ammunition temperature.



Another instrument that is used is a thermometer to determine the temperature of the ammunition. The instrument in the picture uses a laser beam to read the surface temperature of whatever you need to sense. The USAF weather kit has a contact/probe thermometer that you can place in an ammo container to determine the temperature of the air surrounding the ammunition. This is assumed to be the ammo temperature. The method is very accurate once the ammo warms or cools to the ambient air temperature. The laser thermometer in the picture is from "Healthy Motivations" a company that has devices for standoff measurement of temperatures as well as other sensors. Determining the temperature of the ammunition is critical to correcting for the muzzle velocity of the guns.

Anemometers

Hand-held wind meters are fine for determining the winds at the position of the gun. They do not, however, do much for determining the downrange winds. The only way to do that is to link a digital anemometer to a transmitter or have them cable linked back to the position. This means going downrange, which is tactically dangerous, but not undoable. Wind meters are always good to have. You may be in conditions where reading the downrange winds are impossible, so all you can do is go with what you have got at the position. The instrument below (left) is the standard anemometer issued with a portable USAF weather package. It gives highs and lows over a period of time with a digital readout. The other two are commercially available models that are compact and every bit as accurate as the USAF model, but less durable.

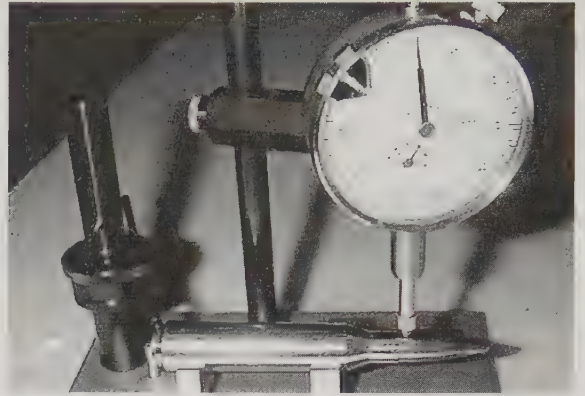


Military snipers must use equipment that they have on hand or purchase special equipment for their purposes. One of the few things that is nearly impossible to special purchase is ammunition. Snipers are limited to the ammunition that is available from within the system. With that limitation in mind, there are some things that a sniper can do to determine which rounds are going to work better for him. One of these methods is to measure the bullet runout—the misalignment of the bullet in the case. By using a runout gauge, a shooter can go through his ammunition round by round and determine which cartridges have their bullets loaded straight in the cases. He can use the bullets with more runout for training and rehearsals. The bullets with the smallest amount of runout are used for final rehearsals and for the real operation. Chapter 9, "Application of Fire," talks about the effects of runout in bullets on the shot group and flight trajectory.

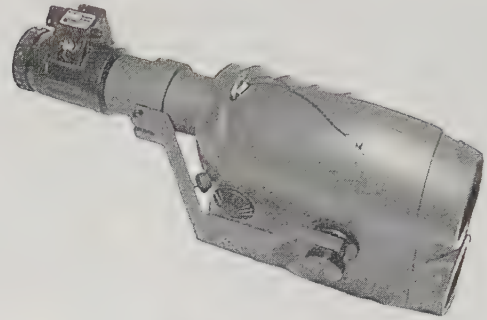
Chapter 7, "Range Determination," covers the methodology and uses of different range-finding equipment. You will read in that chapter why avoiding laser range finders is advised for tactical compromise



LEICA TM-6



RCBS bullet runout gauge.



reasons and why they are not accurate enough at extreme ranges. While all this may or may not apply, the individual operators will select their gear based on mission analysis and availability of equipment.

LEICA Vector 1500 7 X 42

The Leica Vector system is one of the few laser range finders that has the accuracy to perform the mission. Stated measurement region is from 5 meters from 2,500 meters. The stated level of accuracy is 5 meters at 1,500 meters and a claimed accuracy of ± 2 meters. The Leica has the following features:

- Reticle pattern (Mil Dot available) is intermittently illuminated, represents the direction and size of laser on the target.
- Units of measure: meters, yards and feet.
- Angular units of measure: mils, gon and degrees.
- Measurement time up to 120 shots per minute.
- Compass has 0.6 degree azimuth measuring accuracy.
- Data Interface with RS-232 port.
- Approx. 2,000 measures on battery life.
- Weight: 60.3 ounces.



LEICA Laser Rangefinder with Litton 6010 Pocket Scope.

The Leica Vector is capable of the following measurements.

- Distance to target. Can measure and display up to 3 targets in line.
- Distance and azimuth to the target.
- Distance and vertical difference (good for determining slant angle to target).
- Distance between two points.
- Distance and vertical difference between two points.
- Azimuth
- Azimuth and inclination angle.
- Difference of azimuth between two points.
- Difference of azimuth and inclination between two points.

Leica TM-6

The Leica TM-6 is a 6-inch theodolite that is used in surveying for measuring angles. It is a mechanical only instrument that is designed for use in very rugged environments. The theodolite is used to measure angles to determine the range to the target. It does this by reading an angular deflection, either vertically or horizontally. The angles are then plugged into a formula and the result gives the operator the range to the target. These results are very accurate (within 1.6 meters at 1,600 meters). The method is totally passive and has no signature. There is no countermeasure (with the exception of dazzle camouflage) to being ranged by this instrument. An additional payoff is that the optics serve well as a spotting scope, because they are very high quality and high power. The system can be modified to add an ITT or Litton pocket scope to the back of the theodolite for night operations. Theodolites are already in use in most militaries in construction units and field artillery units for survey work.

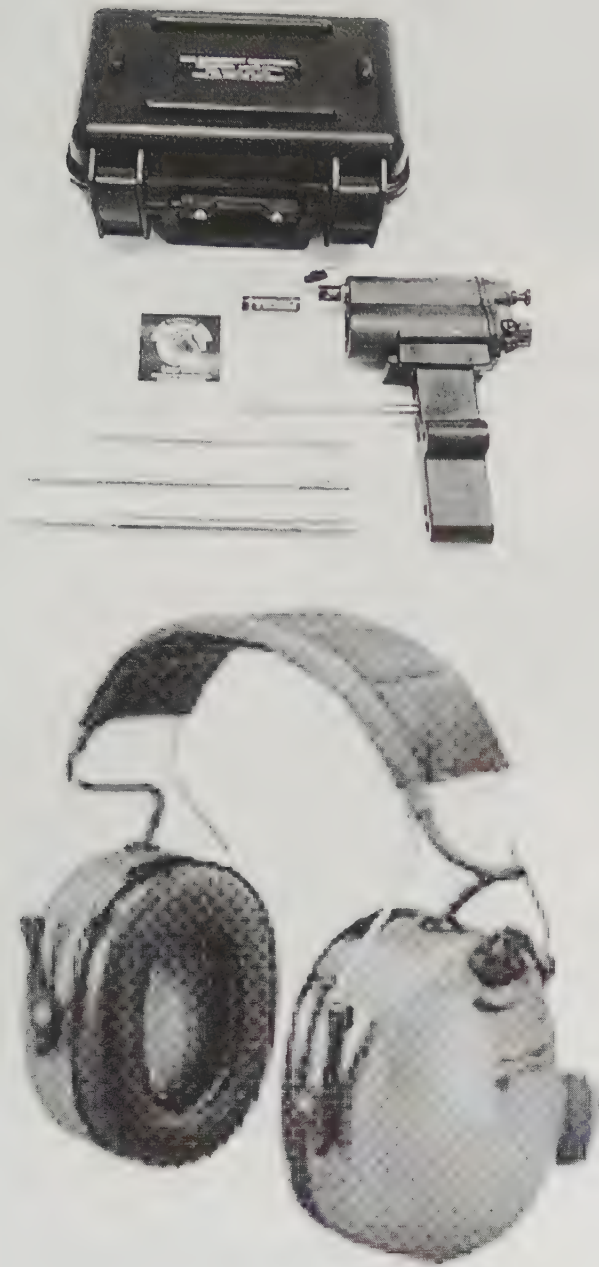
Newer model theodolites in use are electronic stations that don't have a real application in field operations for snipers. The older manual machines are better. They only measure angles, and that's all they need to do. They are available in different levels of reading precision. Suggested minimum angle reading capability is 20 arc seconds or 1/3 MOA. Chapter 7, "Range Determination," has more complete information on these systems and their sniper application.

Laser Pointers

Laser pointers have a couple of potential uses in sniper operations. The major intended use at night is for target designation by the team leader. During an HTI course run in 1996, the standard operating procedure was to use the ground commander's laser pointer (GCLP) as a targeting priority designator. If any operator on the ground saw a high threat, they could ID that target to everyone through a series of coded pulses on the target. For example, three each 1-second pulses signified a direct threat to the team for whatever reason the operator thinks it's a threat.



Ground commander's laser pointer.



The team leader may use the GCLP to designate a target for immediate engagement until destroyed. The beam stays on the target until the team leader decides to lift fire. The laser being turned off was the signal to lift fire. The lasers are infrared only and ARE visible to enemy light amplification devices. They are very intense and powerful lasers. They can be used as a laser sight as they have windage and elevation adjustments. The GCLP can be used in the Point Blank Zero or the Reverse Image Zero engagement method.

Boresight/Collimator Kit

Boresighters and collimators are instruments used to determine the alignment of a rifle scope with the bore of the gun. They can be used to bring a new scope into quicker alignment with the bore of the gun, which saves on ammunition when zeroing.

This boresighting kit comes with the spuds for 5.56mm, 7.62mm and .50 caliber. 2 AA batteries that illuminate a grid for night operations and can be used with night vision system power the system. The vertical bar has index markings for the required locations of the different spuds based on the weapon system used. For sniper weapons systems (which are not specifically marked on the bar) the operator must experiment to see which location works the best. The grid can be zeroed so that the center of the reticle in the optical system is centered on the grid in the collimator. This is not a common feature on most collimators. These boresighters repeat their location very consistently. They are lightweight and reliable.

Hearing Protection

Peltor Electronic Hearing Protection not only protects the operator's hearing against severe damage from shooting the heavy rifles; while wearing these protectors normal speech is detected and amplified.

The operators leave on their hearing protection, talk

back and forth in hushed tones, and hear each other from farther distances while these headphones are amplifying normal speech. These protectors are occasionally used in patrol base situations. They do an exceptional job of detecting snapping and cracking sounds—somewhat better than actual voices that produce much more subtle soundwaves. The Peltors are very good for enemy detection at night when night vision systems are not useful because of light conditions or other problems.

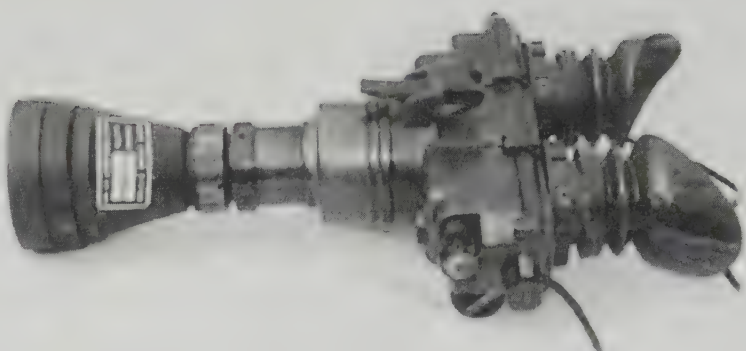
Night Vision Goggles

Litton Industries AN/PVS-7D night vision goggles are the most current issue night vision goggle. They

are generation III goggles and are issued with a 3X amplifier that is used for observation and surveillance. The system runs on AA batteries. Typically, the 7s are supplied with "sacrificial" lenses that are made to protect the sensitive main lenses on the objective and ocular lenses of the goggles. They have a daytime filter/cap so that IR lasers can be daytime tested as well as the goggles themselves. Provisions have been made to mount the 7Ds on the Kevlar helmet.

MEDIUM CLASS GUNS IN SUPPORT OF HTI MISSIONS

Rifles from the medium class were added in the support section as they can provide a direct anti-personnel interdiction to threat targets. These guns are all in caliber .338 Lapua or their older designation the .338/.416 Rigby. This round drives either the 250-grain .338 Lapua bullet or the 300-grain Sierra Matchking bullet fast and hard enough to be supersonic at 1,600 yards under standard atmospheric conditions. That is about the same range as the .50-caliber rifles under the same conditions. Many of the .50-caliber rifles are not capable of the levels of accuracy needed to hit a human target at the extreme ranges. The high quality of all of these rifles in combination with their power makes them ideal anti-personnel guns for the support role in HTI. One of these guns within a four-man team gives that HTI team a good long-range support platform. It has been stated that the .338 Lapua cartridge fills the gap between 7.62mm and .50 caliber. I would offer that the .338 is superior to the .50-caliber rifle in that the 300 grain Sierra bullet is better in its long-rang performance than the military .50-caliber cartridges. The supersonic range is about the same (the defining limit for precision shooting) but the .338 Lapua guns are much more accurate. Note that all guns shown are displayed with the Leupold & Stevens Mark IV, M-1 with the sole exception of the Barrett rifle.



Special Forces Model AN/PVS-7D with 3X amplifier and helmet mounting system.

Accuracy International .338 Lapua Super Magnum

This company was one of the first, but not *the* first to make the .338 Lapua guns. Their system is based on the famous design of Malcolm Cooper. The action is mated to an aluminum chassis that runs from the forearm, under the action and back to the shoulder-piece of the gun. The stock is simply two halves of injection molded



Accuracy International .338 Lapua Super Magnum.



Barrett M-98 Lapua

the front of the stock. The muzzle brake is a smaller version of the arrowhead design used on the .50-caliber gun. The barrel is 24 inches long and weight is 15.5 pounds.

Dakota Arms .338 Lapua Longbow

The Longbow rifle came about in response to a request to Dakota Arms from an agency concerned with airfield security. Using their famous Dakota 76 action they built this rifle. A special steel Lothar-Walther barrel is available with a chrome-moly or stainless steel barrel as the standard. The special steel used in the Lothar-Walther barrel is blended to be extra hard, providing a longer than normal barrel life. A test gun that the author used to develop trajectory data, had an estimated 2,000 rounds on the gun. It was Dakota Arms' first prototype rifle. The stock is McMillan's A-2 with a sliding cheekpiece and a spacer plate extension system. The barreled action is bedded on aluminum pillars and is supported under the chamber by the bedding compound. The construction is the most conventional of all the guns shown in this section, but it was the most accurate of all depicted (with the exception of the M-98, which was NOT shot). The testing was done in the Dakotas in January 1999. Conditions were mostly standard atmospheric, but at times the temperature was around 30 degrees F. The rifle stayed under 1 MOA all the way to the maximum range tested, which was 1,600 yards. At that range, the bullet begins to be destabilized by the transition to subsonic flight. A number of



Dakota Arms .338 Lapua "Longbow".

plastic that are screwed to the chassis. Magazine capacity is 5 rounds.

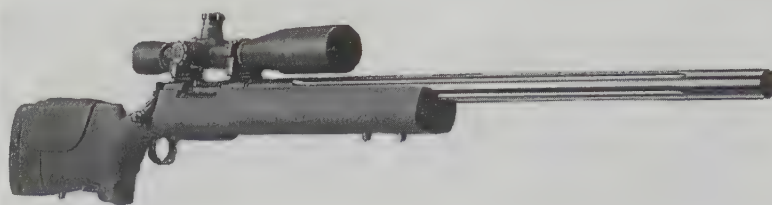
Barrett Manufacturing M-98 .338 Lapua

This gas-operated semi-automatic gun made its debut at the 1999 SHOT Show in Atlanta. The receiver is a one-piece casting that is massive. It is similar in appearance to the Accuracy International stock. Barrett's new scope ring design was shown on this gun. The rings have a floating sub-base that allows the operator to set the angle of the scope to any degree. This allows the operator to use any zero method that he chooses, whether it's the Parallel Bore Zero process used in this book or any other system currently in use. The magazine is a 10 round box and a stud for putting on a Parker Hale bipod is on

keyholes occurred at the transonic range. This rifle was by far the most accurate .338 rifle the author has tested, which includes all but the Barrett M-98.

H&S Precision

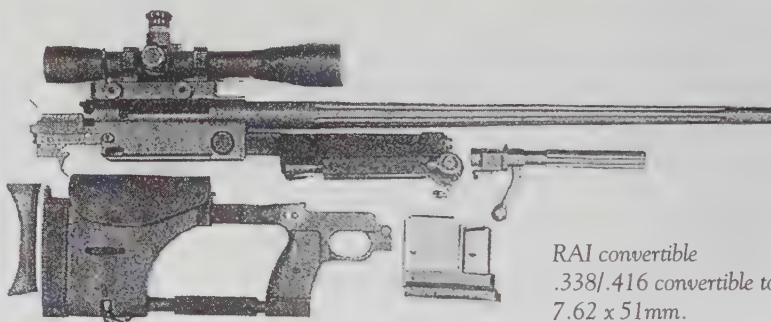
H&S Precision offers two rifles into the .338 Lapua category. The Heavy Tactical Rifle is the standard H&S format. The stock has their patented aluminum V-block chassis within the stock. Magazine capacity is 3 rounds. The gun uses the



H&S Precision .338 Lapua Heavy Tactical Rifle.



H&S takedown .338 Lapua rifle.



*RAI convertible
.338/.416 convertible to
7.62 x 51mm.*

H&S Precision Pro-Series 2000 action of their own design. The rest of the gun is pretty much standard H&S high quality. The stock has an adjustable cheekpiece and an adjustable length of pull assembly.

The .338 Lapua Tactical Takedown System (TTS) is designed to fit into a camera box sized Pelican case. To do this the barrel must be no longer than 23.5 inches and uses H&S proprietary 10X rifling method which is fluted. The stock is the PST26 that includes an adjustable cheekpiece, adjustable length of pull and a pistol grip mounted tail stand. These guns can be set up with another barrel of either .308 or .300 Winchester Magnum and spare bolts. When combined with U.S. Optics SN-3NV, the system is a potent and formidable sniper weapons package.

These next .338 Lapua sniper rifles are a bit older and are offered for a historical look at the rifle. These guns were designated .338/.416 because the cartridges were custom-made for the U.S. Army by Sandia National Laboratories. This was still an experimental cartridge back in 1986/1987 when the Special Operations was considering them for purchase.

RAI M500 Convertible

The RAI M500 Convertible weapons system was offered in .338/.416 and was convertible to 7.62 x 51mm. Eventually the conversion requirement was dropped because the M-24 was being developed to replace

EQUIPMENT USED IN HARD-TARGET INTERDICTION



Earl Reddick's Remington M700 modified for the .338/.416 cartridge.



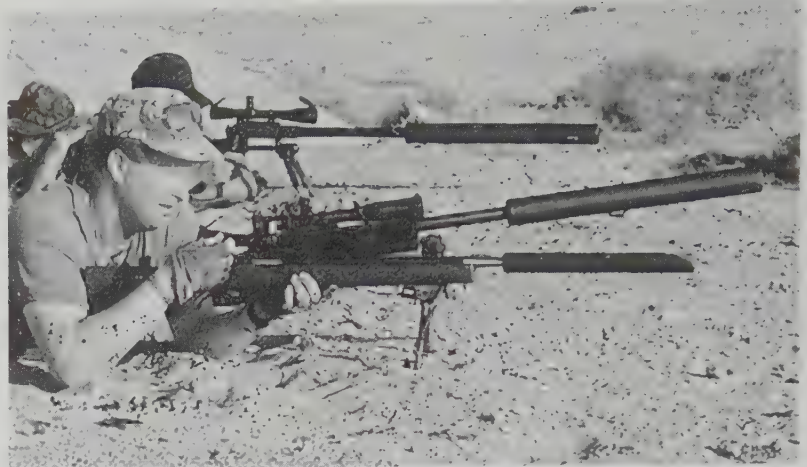
the M-21 rifle. The Special Operations Target Interdiction Committee (the instructor staff of SOTIC) at Fort Bragg, NC, was the first to test this gun. That school has always used bolt action rifles as their basic gun. Remington M700 actions were procured from the Air Force and then upgraded with McMillan (pre-Harris Gunworks) barrels and either McMillan field stocks or their prone competition stocks. SOTIC students still trained with the M-21 system, but by training operators on their own "bolt gun," SOTIC graduates were ready to deal with the new M-24 when it came online. The first M500s were offered with Weaver T-16 scopes. As previously stated, these are competition scopes and are not up to the rigors of military testing and use. The magazine capacity was five rounds. The gun accuracy was reasonable but not exceptional. That limitation however, probably can be traced to ammunition components and not rifle problems. This rifle is also referred to as the Haskins M500.

The Remington M700 Long Action was built to shoot the .338/.416 cartridge. Earl Reddick built it to prove that the Remington action was strong enough to handle the punishing power of the cartridge at that time. The project was successful. A 10-round box magazine was made for the gun. The rifle used an H&S Precision Pro Series stock, the same one as the M-24. The muzzle brake was of Earl Reddick's design. A careful look at the rear of the ejection port reveals the main modification to the M700 action. There is a relief cut to open the length of the ejection port. The stroke of the bolt was also lengthened to allow the bolt to strip off the next round in the magazine.

SUPPRESSED WEAPONS SYSTEMS FOR HTI OPERATIONS

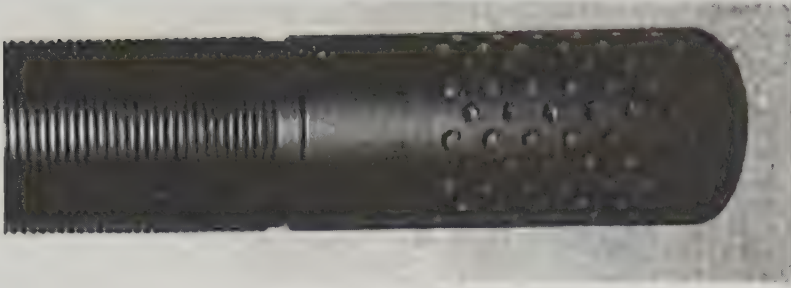
The use of suppressors on .50 caliber rifles is nothing new. To most, it would seem nearly impossible to contain the energy of these guns and make it quiet. It has been done, however, and by more than one manufacturer. Some would argue that it isn't necessary to suppress a weapon that is intended to shoot from such a long range. There are three reasons why putting a can-type suppressor on a heavy-class gun makes sense:

- **Position signature reduction.** The standard muzzle brakes that are on the .50s cause a huge disruption at the gun's position. This happens in all environments but dry concrete. The can suppressor directs the blast straight downrange and doesn't cause such a dust blast.
- **Recoil Suppression.** When correctly designed, the suppressor cuts down on the recoil a great deal. A version that is on the Barrett M82A1 rifles causes the bolt to blow back too hard and creates extractor failures by blowing them off of the bolt.
- **Noise Suppression.** The suppressors that are out on the market all do a good job of keeping the noise down. The bullet stays supersonic and there is not much of a velocity loss. Another payoff for having a suppressor on the gun is to hide the noise of the gun for enemy forces you don't know are close by. You cannot assume that the area is clear enough of enemy that patrols may not hear the gun. Because of security concerns of this technology, details of the suppressor packages are not printed.



OPSINC Suppressors

Phil Seeberger of OPSINC has long manufactured suppressors for special operations units. His cans have seen action on the M-16, M-4, M-14, M-21, M-25, the H&K 21 Light Machine Gun, many bolt-action sniper rifles and at one time on tanks for the German army. The OPSINC suppressor mounts different than any other mounting system out there. The barrel diameter is reduced from the muzzle for a few inches back toward the action. The barrel has a sharp taper on it (about 25 degrees) and the muzzle is threaded. As the suppressor is threaded on the barrel, the rear of the can makes contact with this tapered area. This tensions the system and pre-stresses the final 8 or 9 inches of the barrel. This actually causes the gun to be more accurate. In all



This .50-caliber suppressor with a built-in muzzle brake gives the best of both worlds. It is manufactured overseas and is like nothing built in the United States. The problem is that the signature at the gun position is increased because of this additional venting at the top and sides of the brake.



The Heckler & Koch Mark 23 offensive handgun.

associated with HTI operations. Certainly there are more guns than are listed in this book as well as there are more optics and supporting systems. The systems have been tested, officially or unofficially, and some have been adopted for use.

The heavy-class of guns has long been the cause of some controversy and some in-house battling within the procurement divisions at the respective services. As this is being written, the decision on which .50 caliber will be the next heavy-class gun is being made.

weapons systems with this tapered mounting system, the accuracy was improved over the standard barrel.

Heckler & Koch Mark 23 Offensive Handgun

This weapon was developed as part of a competition between H&K and Colt to develop an offensive handgun for special operations. The gun shoots a .45 caliber +P round. It uses a 185-grain high-energy load. The pistol is equipped with a suppressor and a laser/white light aiming module. Why is this gun in this chapter? The weapon makes a good security weapon to take out the onesies and twosies that may stumble onto the team. This doesn't mean that anyone got away with anything. At best it gives the team more lead time to leave the area if possible. It is much quieter than the M-4 with its suppressor or any of the sniper rifles with theirs.

This chapter was intended to introduce the reader to the equipment

CHAPTER 3

Care and Maintenance of the Heavy Rifles

The heavy-class rifle many times is constructed a little differently than the rifles in the medium and light classes, but there are a couple of companies that construct their .50-caliber guns along the same lines as the more conventional weapons. One should understand the different methods of construction because the maintenance procedures differ based on these methods. This chapter is going to cover several subjects regarding care and maintenance:

- Sniper Weapons System (SWS) methods of construction.
- Heavy sniper rifle operational checks.
- Match grade barrel break-in procedures.
- SWS cleaning methods.
- Prepping a heavy sniper rifle for movement.

SWS METHODS OF CONSTRUCTION

The two major categories of construction are bolt-action and semi-automatic. Within the category of semi-automatic rifles there are gas-operated systems and blowback models. A third category of weapon operation is the self-ejecting bolt-action rifles. These guns have systems that unlock the bolt, eject the expended case, and then move the bolt to the rear, where it stays. The operator then moves the bolt forward and locks it down. Many people only want to shoot the rifles they own. A number of these people have the desire to understand how they are built. You may be surprised to learn that there are a variety of construction methods used in building SWS and match guns. Here is a generalized list:

- Pillar bedding and free-floating the barrel
- Aluminum block bedding (V-block) under the receiver
- Skeletal structure guns

- Barrel block methods. (Free-floating the receiver)
- Chassis or superstructure mounted to the receiver (Accuracy International uses this method)
- Semi-automatic rifles

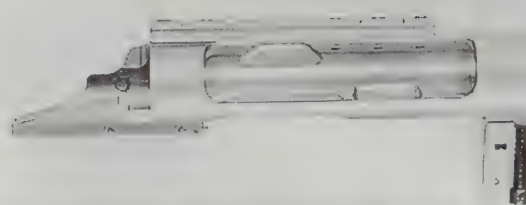
The Conventional Bedding Process and Free-Floating the Barrel

This is the most common method of improving a rifle's accuracy. Many hunters as well as match shooters and snipers have this basic procedure done to their rifle. There are two processes involved in this method.

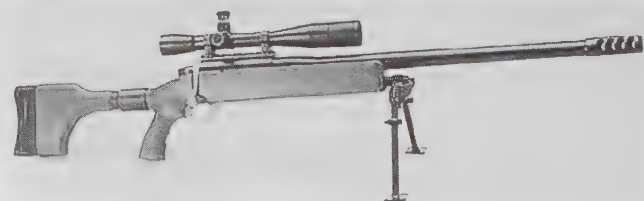
The first is to remove the barreled action and clean out wood or fiberglass material in the barrel channel. You have to have enough material removed so that when the action is bedded, no part of the barrel is resting on wood or fiberglass in the forearm area of the stock. Once this is done a release agent is painted to the metal parts of the action. The receiver area of the stock is relieved so that there will be a good, thick pad of bedding material under and around the action. Necessary areas of the stock are masked and the action and barrel are centered in the stock. The bedding agent is pasted into the stock and onto the receiver. The action is pressed into the stock.

Masking tape is placed on all sides of the recoil lug except the rear face of the lug. This is so that the action has no binding when it is pressed into the bed. The barreled action must be held securely, yet without unnatural tension in the action. If you do not mask the recoil lug, stress will set up in the receiver every time the rifle is fired. This stress will slowly move the action around in the stock (hard to believe but it happens). The whole mess is allowed to cure for 24 hours. Excess material is milled away. It is also suggested that the trigger guard is bedded into the stock. This provides a solid and even base for the trigger guard to lay on as the guard screws are tightened on the rifle.

You should experiment with different guard screw torque specifications (in. lbs.). For example, 35 in. lbs. in the front and 25 in. lbs. on the rear screw. At a certain specification, the rifle will shoot more accurately than with other screw torque specifications. This messing around with torque specs is only required when there is no aluminum or steel pillar between the action and the floorplate.



The McBros .50-caliber repeater action.



These are examples of the more conventional construction methods of bedding the action over aluminum or steel pillars. These guns are the most similar to smaller light-class guns.

Pillar Bedding and Free-Floating the Barrel

The process of pillar bedding the barreled action is the same as with the conventional bedding process. There is one major difference, though, and it counts for a lot—there is no messing around with torque specifications.

When the pillar bedding process is used, the guard screw holes are enlarged with a Forstener drill bit. This is a very rigid drill for cutting large diameter holes in stock material. Aluminum or steel pillars are bedded in between the receiver and the floorplate. Many companies also bed under the chamber area of the barrel. This reduced the whipping stress on the action itself. It also removes the “fulcruming” action at the front of the receiver. Bedding compound is added to the floorplate area. After the bedding compound has had a chance to set up and become pliable yet cuttable, the excess is cut away from the action and the barrel. The action is allowed to set overnight.

The next step is to take the stock and barreled action and placed them in a jig in the milling machine vise. The area where the floorplate goes is indexed to be level with the bed of the mill. A 1/2-inch bit is used to cut the floorplate area of the stock to the same level. This includes the pillars and excess bedding compound in the floorplate area. The guard screws are removed and the action is lifted out of the stock. The result is that the pillars are perfectly bedded and mated to the action. Once the excess compound is cleaned up and machined off, the floorplate and receiver are installed. The guard screws are inserted and torqued to 65 in. lbs. This is the same torque specification used on the guard screws on the M-24 SWS. This is a constant specification. This 65 in. lb. constant is possible because of the metallic pillars between the receiver and floorplate. In the conventional bedding process, the wood or loose-weave fiberglass can actually compress slightly under pressure. In addition, changing MET conditions such as air temperature can cause the non-metallic materials to contract and expand. This slightly alters the torque specification used in the guard screws. When you use metallic pillars, this expansion cannot take place. The coefficient of expansion for steel and aluminum is minute compared to wood or fiberglass.

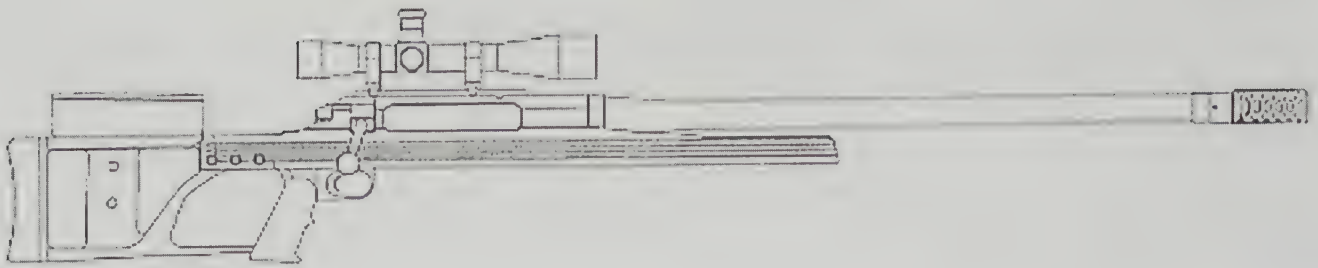
Another benefit of using this process is that flat-bottom receivers such as Winchester and Sakos usually will return to zero after removal and replacement of the stock. Round bottom receivers (Remington) usually require a rezero, but not always.

Aluminum Block Bedding (V-block) Under the Receiver

The concept of the V-block is used in Benchrest competition rifles. It is not as common as the pillar bedding process. A good example of the V-block concept is the H&S Precision M-24 stock. This is the stock used on the M-24 SWS used by U.S. Armed Forces. Instead of pillar bedding, a V-block made of aluminum is machined and inserted into the stock during the stock molding process. The block on the H&S stock for the M-24 and Sendero Remington rifles only extends from the forearm all the way back into the pistol grip area of the stock. On early model Remington M700 PSS models, this block only extended the length of the action.

The V-block concept is that the round receiver lays perfectly centered in the V-block. Once you remove the action from the stock, reinstall it, and re-torque the guard screws, the weapon will automatically go back to the correct zero. My experience with the M-24 is that this is generally true. There have been some problems with the black stock material overlaying the bearing area of the aluminum V-block. This means that the receiver is bearing against the black stock material instead of the aluminum V-block. This can be bad, especially if the black material causes a stressing action in the rifle as the guard screws are torqued down.

For the military weapons systems, this stock provides a yet unmatched ability to replace stocks in the field without having to rezero. It is preferred to rezero, of course, but usually not necessary. I have talked with some service armorers that stated that they preferred to bed over the aluminum block. They stated that the rifles shot better this way. I would say that they do not understand the V-block concept, why it is used, or how to check the correctness of the system. In the section on military sniper weapons systems and their operational checks, the method on checking this is explained. The correction of this error is also explained and it is quite simple.



The only commercially built V-block heavy-class rifle is the Armalite AR-50.

Skeleton Structure Heavy Rifles

This is the most common method used on rifles that have been adopted for the military or heavily considered by them. The exceptions, of course, are the M-88 rifles adopted by the U.S. Naval Special Warfare community. These rifles are basically receivers with barrels attached, a buttstock and pistol grip assembly, and a bipod to hold the whole mess off the ground. This method is one of the most durable and foolproof construction techniques of the whole class of rifles. There is no bedding compound to worry about damaging. There is no complex method of attaching the barrel to a barrel block and then attaching the stock to this piece, or the other way around. This technique guarantees a free-floating barrel because the basis of the gun is only barrel and action. There is no third major component (the stock). A lot of unnecessary weight is also eliminated. The rifles that are made this way are some of the lightest rifles in the class as well as the most durable.

Barrel Block Methods (Free-Floating the Receiver)

On most rifles where the barrel is floated there is a great deal of stress on the receiver. Vibrations are set up when the round is fired. The vibrations start in the receiver and are then transferred to the barrel. Vibrations in the rifle are a total result of the round being fired. Changes in groups occur when ammunition of a lower quality is used against ammunition of a higher quality (among other things). In the past, heavier barrels were attached to strong and stiff receivers to compensate. The act of free-floating the receiver:

- Eliminates the need for a stiff receiver. By floating the receiver, this part of the formula is taken out of



These are some of the lightest rifles around: Included are the Daisy M600 in .50 cal BMG, the 14.5 X 114mm, the Windrunner .50 BMG, and the original Soviet PTRD anti-tank rifle. The PTRD is one of the oldest heavy-class anti-materiel rifles.

the whole equation. The receiver now only chambers rounds of ammunition. It also serves to hold the trigger group.

- Isolates the receiver from the barrel. Obviously, vibration will still occur in the receiver. Since the receiver free-floats, it can move independently of the barrel. By the method used to attach the barrel to the stock's V-block (see below) the vibrations will be dampened heavily by the massive aluminum block attached to the barrel. There is still 1.205 inches of steel under the .25-inch thick aluminum barrel block.

Free-floating the receiver is accomplished by bonding an aluminum block 9 inches long to the barrel directly in front of the receiver. The barrel is left straight (1.205 inches outer diameter, or OD) for 9 inches and then the taper begins. An aluminum block is machined (usually round, but octagonal has been used). It is lathe-bored .015 inch larger than the OD of the barrel. Both surfaces are rough machined so the stainless steel bonding agent has a better gripping surface. This block is centered on the barrel by placing precision tapered centering bushings over the barrel. Stainless steel bedding compound is applied over the barrel and inside the barrel block. The block is then left to cure for 24 hours.

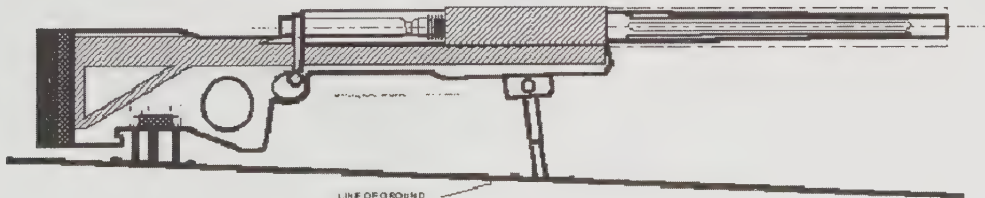
The barrel block is the part of the barreled action that is attached to the stock. This is accomplished by the use of a V-Block. The rifle uses a 6061 T-6 aluminum V-block. The V-block is bonded into the forearm area of the stock. The barrel block is attached to this with 4 high-grade steel bolts. On lighter recoiling guns (up to .300 Winchester Magnum), the bolts serve as the recoil lugs. On larger rifles (up to 15mm) a recoil lug at the front of the barrel block interfaces with the V-block. The outside diameter of the barrel has a step machined in it that interfaces with a step on the inside of the barrel block. This serves as an internal recoil shoulder inside the barrel block. Thus, all of the recoil forces are transferred to the stock.

Chassis or Superstructure Mounted to the Receiver

The best examples of this method are the rifles built by Accuracy International. You can't tell by looking at the rifle, but there is no real stock, per se. Malcolm Cooper designed this rifle, and he did a fine job. When you look at the rifle from the side, you will see a number of Allen-head screws along the side of the stock. These screws mount two halves of stock shells to a chassis that is under the stock sides.

The way the chassis method works is that a steel chassis (in the Accuracy International case) is welded to the receiver. This chassis runs from the receiver back all the way to the rear end of the gun. This chassis serves as the method of transfer for recoil from the barreled action to the recoil pad and shoulder of the shooter. The recoil pad is attached to this chassis. The two halves of the stock are also attached to the chassis. This entire system precludes any possible zero changes, because there is no real action to stock mating. The critical component, the chassis, is literally part of the action. If you break either of the stock halves, you replace them. If you are in the field, you tape it, splint it, or whatever works. The chassis could even be bent, and the weapon will likely function as advertised.

One company will be building heavy-class guns using a combination of the barrel blocking technique and the chassis super-structure technique. In this case the barrel block and chassis are CNC machined out of one



The barrel block is integrated with the rail superstructure beneath the action. It is all one piece with a free-floating action.

piece of 6064 T-6 aluminum. The barreled action is then bonded into the barrel block and the stock halves are screwed to the chassis. A recoil pad is added to the rear end of the stock.

The Semi-Automatic Rifles

The other group of heavy rifles are constructed to be semi-automatic guns. The most famous of these, of course, is the M82A1 Barrett Light .50, a semi-automatic gun with a short-stroke, blowback method of cycling the bolt group. When the gun is fired the barrel starts to move backward toward the rear of the gun. The barrel only moves about 2 inches. At the end of that short stroke, the bolt unlocks and the bolt carrier moves rearward with about a 12-inch stroke. The expended case is ejected and a new round is stripped from the magazine. The barrel is already fully forward when the bolt meets with the locking lug recesses in the barrel itself. It's a very clean and quick process. Recoil is also kept down using this method.

There are only two gas-operated semi-automatic rifles that have received great attention by military units within the United States and overseas. These are the Harris M-96 and the Pauza P-50. Both guns are based pretty much on the same chassis design and gas extracted from the bore of the gun is transmitted via gas tube to the bolt carrier. All gas-operated systems work pretty much the same, at least in the heavy-gun design. These guns were designed with multiple repeat shots and faster target re-engagement in mind. They are magazine-fed with a 10-round magazine.

Combination Self-Ejecting Bolt-Action Rifle

The combination self-ejecting bolt-action rifle is currently represented by only one rifle. This is the Steyr AWS-2000 15.2mm rifle. The cycling of this gun is semiautomatic extraction and ejection and manual feeding and locking. An operator places a 15.2mm cartridge on the feed rail inside of the action and the pushes the bolt forward and locks it down into place. When the rifle is fired, the bolt unlocks, moves to the rear, ejects the spent case, and stays locked to the rear awaiting a fresh cartridge.

Without a doubt the heavy-class of rifles is the most exciting as far as design and innovative thought are concerned. Not in any other class of guns is there such diversity of design and just plain visual attraction. While some of the guns are fed like other smaller rifles, this one has a different method of loading. The methods of cartridge feeding are:

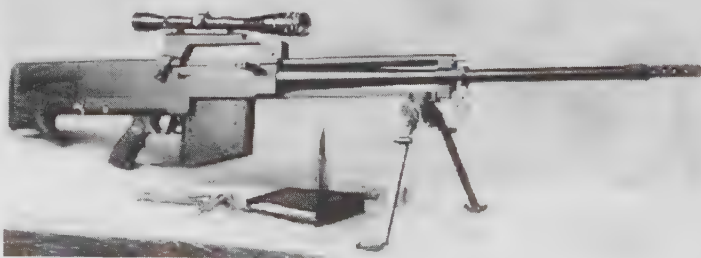
- **Single Shot.** An individual round is placed on the feed tray within the action itself and the bolt is pushed forward, locking it down.
- **Repeaters.** These are magazine-fed rifles where a bolt strips a round from a magazine and feeds it into the chamber. The bolt is either locked down by hand or rotated into its



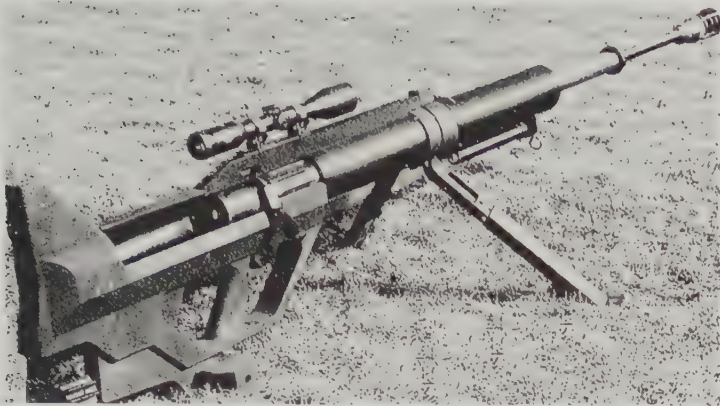
The M82A2 Light .50 by Barrett.



Harris Gunworks M-96



Pauza P-50



The Steyr 15.2mm rifle.



A bolt with a cartridge from the McMillan M-88 rifle.

locked position by the design of the semi-automatic system.

- **Shell Holder Design.** This design has the rifle cartridge attached directly to the bolt face by means of a U-shaped cup on the front of the bolt face. This cup holds the round by its extractor rim. The cup is also the strongest form of an extractor on any rifle made. They have never failed.

In some earlier rifles, the shell holder method caused some stress for shooters as there were a couple of instances of the rounds going off as the bolt was rotated into the locked position. No injuries were reported, but the weapons were locked down while an investigation was conducted into the problem, which was quickly corrected.

HEAVY SNIPER WEAPONS SYSTEMS OPERATIONAL CHECKS

As you have seen in Chapter 2 and this chapter, there are many different sniper rifles and methods of construction, operation, and teardown. The operational checks and the cleaning processes are broken down along the same lines as their

methods of construction. Each type of construction has different points that need to be checked for operational readiness. Later in the book you will learn that a team has the option of using only one gun or up to three per four-man team. If you end up choosing that one gun, you want to make damn sure that it is operationally capable and will not fail when the time comes for it to do its job. They are NOT fail-safe and many errors are due to operator oversight. The following is a preoperational checklist that was developed by snipers at 1st SFGA. It applies to both iron and optically sighted rifles. Pick out the stuff that applies and forget the rest.

General Checks for All Rifles

- Ensure that the rifle is clear.
- Check the barrel crown and inspect it for damage. (This is especially important for muzzle-brake rifles as the crown is frequently ignored. It is also sometimes abused because operators tend to want to dig around inside the brake with a rod and patch trying to dry it out. Be careful with the crown).
- Secure the front sight mount to the barrel.
- Torque the action screws to the specifications.
- Set the stock at the correct length of pull.
- Secure the rear sight mount to the receiver.
- Function the bolt to ensure bolt releases are not stuck, allowing the bolt to come out of the action.
- Check that the front sight (if used) has the correct insert in place.
- Make sure the rear sight (when used) has the proper elevation setting and is corrected for MET and ENV conditions.

- Check the screws that attach the scope base to the rifle, making sure they are tight.
- Place the scope on the mount in the correct position, and torque it into place. (Get behind the gun and make sure that eye relief is correct.)
- Adjust the elevation and windage (spin drift) for the range at which you are shooting.
- Adjust the reticle focus to ensure a crisp and clear image.
- Adjust the parallax for the range.
- Dry fire to get a feel for the trigger and make sure that it actually works.

HEAVY RIFLES BUILT WITH CONVENTIONAL OR PILLAR BEDDING

All rifles that are conventionally bedded or bedded with metal pillars have some specific items that should be inspected/checked before, during, and after operations. Virtually all of the .50-caliber rifles that use this method of construction are using round actions such as the McBros action. These are fine actions, but they have the same return to zero problems that are inherent with the Remington action, or round actions in general. The recoil lug is the major piece of metal that is going to align the system when it is re-installed in the stock. The recoil lug is relieved, however, on the sides, front, and bottom to ensure that it doesn't bind in the bedding.

Actions that are square on the bottom such as the Winchester or the Sako have many 90 degree angles that are used to re-seat the action in the bedding. They do this quite well. The zero rarely is affected on these flat bottom actions, but it does happen.

Technical Inspection

A thorough technical inspection of the conventionally bedded heavy SWS should be performed each and every time the weapon is placed into action. The following is a list of initial and subsequent checks to be performed on these heavy rifles. Also provided is an operational check of the weapon before it is placed into action. For civilian and military shooters that own a conventionally or pillar-bedded rifle, these checks are the ones to go with for your type of rifle construction.

Initial Checks on a New Weapon

These are checks that you will perform on a weapon that is new, or is newly assigned to you. It is also performed on any weapon of questionable accuracy or reliability. This is a list of gunsmith precision checks to ensure that factors that affect the rifle's accuracy and reliability are acceptable.

Stock Checks

Before removing the barreled action from the stock, you will check the barrel channel clearance. This should be checked by using three business cards as minimum. Some will state that a dollar bill is all that is needed. When the weapon is fired, strong harmonic vibrations are set up in the barrel. These vibrations are easily strong enough to flex a barrel more than a thickness of a dollar bill. The barrel WILL slap the barrel channel of the stock. If there isn't enough room for 3 business cards, note this for later work.

Disassemble the rifle. Separate the barrel action group from the stock. Note as you remove the guard screws if they seem to bind in any way while removing them. If the screws do not freely turn (as you would with your fingertips) note this for later repair. Lay the barreled action down and look at the stock.

Look at the recess in the stock where the recoil lug goes. The recoil lug on the barreled action should bear on the bedding compound ONLY on the reverse (the side of the lug that faces the rear of the action) side of the lug. It should not bear on the bottom, sides, and the front of the recoil lug. Look inside of the recess for bearing marks on the bottom, sides and front of the recess. Rarely will you see marks on the front of this recess, though sometimes there will be marks on the sides. More likely, there will be wear marks on the bottom

of the recess. This must be fixed. Remove the action and turn the barreled action so the recoil lug is facing up. With a large file, carefully remove material from the bottom of this lug. Use a black magic marker to mark the bottom of the lug. Lay the action into the bedding compound. Remove the action and see if the lug left an ink mark in the recess. If so, remove more material from the bottom of the lug, then check again.

Check the sling swivel studs. It is recommended that you Loctite the studs with #271 Loctite.

Check the Barreled Action. Check the crown of the barrel. There should be no chips around the crown of the muzzle. Now you will probably note dents and dings on the OUTSIDE of the barrel edge. This is OK. The important part is the spot right where the bullet exits the bore of the barrel. The smallest ding will cause an uneven gas release around the base of the bullet. This is the primary cause of keyholing bullets at short ranges.

Visually inspect the throat of the barrel

The throat is the area just in front of the chamber. It is where the rifling begins. This is the place that wears out on a gun when it has too many rounds through it. Look and see if you can see crisp beginnings on the lands and grooves. On barrels with 2,000 or more rounds, these lands will be eroded and in extreme cases the rifling will not begin for up to 1 inch down the bore.

Thoroughly clean the bolt locking lugs and degrease them with alcohol

Mark the back (locking surface) of the lugs with a black magic marker. Place a fired case in the chamber of the barrel. Lock the bolt into the receiver and move the handle up and down two or three times. Remove the bolt and look at the locking lug contact surfaces. There should be even witness marks on both of the lug mating surfaces. Many times you will have full contact on one lug and only partial contact on the other. Anything less than 75 percent contact on the other lug is unacceptable. Check the outer perimeter of the lugs for scratch marks that may be caused by scope mount screws or action screws protruding into the receiver. While the bolt still may close while touching a screw, this will definitely screw up the precision of the gun.

Check the bridge mount

Some bridge mounts are part of the actual receiver and cannot possibly come loose. If you have one that is screwed to the receiver, carefully loosen the screws that hold the rear of the bridge mount to the receiver. Have a partner maintain heavy downward pressure on the base so that if the base is spring it will not rip the threads out of the receiver. After the screws are removed, carefully release tension on the base. It should NOT spring up. The base should rest evenly on the forward and rear receiver rings.

Check the scope ring

Rifles that do not return to zero are a major problem. One of the problem areas is where the rings mate to the base. Look at the forward ring where it mates to the base. Look at the claws that grasp the underside of the base. On many rifles these claws bear directly on the receiver and bear only a little bit on the base. The nuts will torque to 65 in. pounds. However, they will be torquing on the receiver. This is a major cause of bad return to zero. Fix this by filing off metal on the bottom of the bearing claws. Do this until the claw bears only on the base and has good clearance on the receiver. The rear scope ring usually has more than enough clearance, but check it anyway.

Check the trigger

Checking the pull weight of the trigger is only possible with a trigger pull gauge. The trigger pull weight should be 2.5 to 4.5 pounds. It is preferred closer to 2.5 pounds than 4.5 pounds. Ultimately, the trigger weight is set for the operator and his own confidence/training level. DO NOT rely on your best guess to determine the pull weight.

Additional checks for precision

Place the stock on its bipod legs or in a vise. Lay the barreled action in the bedding compound. On some rifles you will note that the barrel does not lay directly in the center of the barrel channel. Ignore this, as there is nothing you can do about it and it does not affect accuracy.

Once all problems are identified and the rifle is ready for reassembly, remove the scope and lay the rifle on its bridge mount with the magazine well facing up. Open the magazine floor plate. Lay the trigger guard in the trigger guard recess. It should lay in with no forcing. If there is tension, use a piece of coarse sandpaper to relieve this tension.

Lay the trigger guard into the recess. Drop the forward guard screw into the hole in the trigger guard. It should drop freely. If it does, then finger-tighten this bolt only—do not tighten with a torque wrench. Drop the rear guard screw into its hole. This also should drop freely into the hole until it drops into the receiver. If it does, then tighten this bolt finger tight. If any of these two bolts catch or bind when you finger-tighten, you will have clearance in the holes in the stock.

After you identify a hole that binds the guard screw, run the screw in and out a couple of times to leave a scuff mark inside the aluminum guard screw hole.

Remove the screw, trigger guard, and barreled action. Use a 1/4-inch round file and file out the hole enough to clear the guard screw. Replace the action and trigger guard and check the clearance. Remove material as needed to clear the guard screws. The roundness of this hole is not important; the clearance of the hole is. Use the torque wrench and torque the screws in order of front to rear.

Stand the rifle on the butt plate. Place the tip of your index finger at the place where the barrel overhangs the barrel channel of the stock. Maintain only light pressure with the finger tip. Use the Allen wrench and slowly loosen the front guard screw. As it loosens up, you should NOT feel any upward springing of the barrel away from the stock. If you do, note this and continue the check. Retorque the forward screw. Place your fingertip at this joint again. Loosen the rear guard screw in the same manner as the front. If there is movement note this and then retorque the screw.

If the barrel moves away from the stock during either the loosening and tightening of the guard screws, one of more of the following conditions may be present:

- The action was incorrectly bedded.
- The receiver is warped.
- The barrel is grossly misaligned with the barrel channel and as the screws are tightened, the barrel is being drawn along the inside the barrel channel. This pushes the side of the stock out and the barrel in the opposite direction. This is major bad news.
- The barrel is bent and is rubbing the barrel channel as above.
- There is a bent guard screw.

The bottom line is if there is barrel springing, the gun is nonoperational and should be repaired by the gun shop that built the rifle.

HEAVY RIFLES BUILT WITH A V-BLOCK SUPPORTING THE RECEIVER

The V- block method under the receiver is a sturdier way of achieving the same goal that the conventional/pillar bedding process uses. An actual “V” is machined out of a block of aluminum and inserted into a stock, or the chassis superstructure in the stock itself and the action is bolted into this. That is the case with the Armalite AR-50 rifle. Armalite is the only “large” company making guns this way. Without a doubt there are a few Benchrest guns (short and long range) that use this method. The rest of the rifle’s readiness checks are the same as the process for conventionally/pillar bedded rifles. The only difference are the checks that an operator can do on the V-block under the action.

Some of these checks can be done at operator level, but there is one check that needs to be done by a machine shop. Any machine shop with a mil and a dial indicator can do this check for the operator. The entire rifle need not go, only the stock/V-block assembly. Here are the checks that are done on a V-block system:

- Barrel channel clearance. While the Armalite AR-50 has a huge amount of clearance between the stock and the barrel, some custom rifles may not. They may be more similar to the conventional/pillar bedded guns. Check the barrel clearance with three business cards as in the previous section.
- Disassemble the rifle. Remove the guard/action screws. As you break the tension loose, they should go to a free spin very quickly, in less than one-quarter turn. Once they free spin (if they do), they should be able to be removed by fingertip turning only. If a guard screw rubs the inside of the hole in the block, you must use a round file and clean out the hole so that the screw does NOT rub. This is not a precision process—just clean out enough to relieve the touching of the screw.
- Look at the recoil lug recess area. Not all V-block guns will have this recess as different methods are used to control the recoil of the gun. If yours has this recess, check it for marks that may indicate that the lug is rubbing on somewhere other than the part that the rear of the lug makes contact. If there is contact on the sides, bottom or front, you must remove lug material to clear this area. Contact with the bottom of the lug will cause huge problems with zero repeating and wandering shot groups.

Look for contact marks on the V-block. If the action is laying true in the V-block, there will be a long, narrow black streak down the length of the block where the action should make even contact. These marks should run the entire length of the action and should be consistent the whole way. If there is a point at which there is a gap in the mark, or even worse, if the mark ends halfway up one side or the other, you will have to have the block checked in the following manner:

- The stock assembly is clamped into a vise on the milling machine table. The following steps are then performed on the V-block channel.
- The block is dialed in so one side of the V-block is perfectly parallel to the milling head from one end to the other. This is done by running the stock back and forth under the dial indicator, watching the deflection on the needle of the indicator.
- One end of the stock is gently tapped up or down until the dial indicator shows no runout from one end of the block to the other.
- Once no runout is achieved, the table is moved in or out so that the dial indicator makes contact with the other side of the V-block where the action lies. Move the table so the dial indicator is located at one extreme end of the block. Carefully crack the table, moving the stock/block under the dial indicator and watching the needle deflection.
- There should be absolutely no difference in the runout measurement at the extreme ends of the block for one-third the length of the V-block, from one end or the other. If there is a slight deviation in the center of the block, it is OK if the deviation is deeper than the two ends of the block. This would indicate a low spot in the rail on that side.
- If there is a high spot, the gun will NOT repeat zero and the groups will float.
- Move the dial indicator to the original side again and check that rail using the same criteria as above.

If there is deviation, a good machinist can remachine the mating surfaces perfectly. It is a simple clean-up pass and can be done while the stock is in the vise.

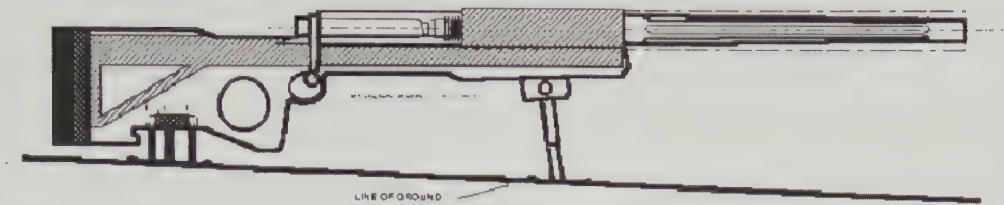
SKELETON FRAME GUNS

These rifles (such as the Daisy M600, AMAC, and the Haskins) have a much more cut-and-dried maintenance checklist. They have no stock, guard screws, V-block or barrel channel to check. All of the actions on these skeleton guns have shell-holder bolts and there is no open port. Scope bases have no long gap to bridge and there is a much smaller chance of bridge mounts being warped or being incorrectly machined. Apply the points that are mentioned in the above two methods as needed to the skeleton rifles. There are some specific points to check, however, because of the different design of this type of rifle:

- Thoroughly clean the bolt locking lugs and degrease them with alcohol. The shell holder bolt designs have three locking lugs. This is a much stronger design but it also sets up a problem with even and total contact on the mating surfaces between the lugs and their matching surfaces in the receiver itself. Mark the back (locking surface) of the lugs with a black magic marker. Place a fired case in the chamber of the barrel. Lock the bolt into the receiver and move the handle up and down two or three times. Remove the bolt and look at the locking lug contact surfaces. There should be even witness marks on both of the lug mating surfaces. Many times, you will have full contact on one lug and only partial contact on the other. Anything less than 75 percent contact on the any one of the three lugs is unacceptable.
- Machinist's Check on the Scope Mount. This check can be done on all rifles with the Picatinny rail mount design. The action is placed in a vise on the table of a milling machine. Touch a dial indicator on the receiver and run it the length of the action, while tapping the entire unit up or down to get the receiver parallel to the mill table. Once the action itself is set up with no dial indicator runout, you can check the base. A dial indicator is touched on the front of the bridge mount on one of the top mating surfaces of the mount. Run the dial indicator the length of the base while checking the deflection on the needle of the dial indicator. There should be no deflection on the needle. Any deflection indicates that the base has a warp in it, or was incorrectly machined or incorrectly installed. The rifle should be returned to the manufacturer for corrective action if there is a discrepancy in the runout measurement.
- Checks of the Tension Rod (Tuning Fork Principle). The tension screw that is used on older Haskins, RAI, and current AMAC guns should only be checked by the manufacturer. Once a year it is recommended that the gun is returned to the manufacturer to have this specification checked.
- Incidental Trigger Release. The problem of incidental firing of a cartridge when the bolt is closed has long ago been fixed. That doesn't mean that some of the older guns that are out there are not capable of doing the same thing. The problem with this is that you don't know when it is going to happen and simply putting a primed only case into the chamber and closing the bolt, with no incidental release, doesn't mean anything. Ship the older guns to the manufacturer for inspection and any work that needs to be done on these. Frequently work the safety on the gun to see if taking the safety off will release the trigger. This also happened a couple of times with these guns. With any shell holder bolt design, avoid slamming the cartridge into the receiver too aggressively.

HEAVY RIFLES BUILT WITH THE BARREL BLOCKING AND CHASSIS SUPERSTRUCTURE METHOD

This rifle is still in prototype stage and the calibers (other than .50 BMG) are not final. Certainly, it is going to be offered in more than one caliber. Barrel blocking is achieved by bonding the steel barrel directly to an aluminum block and superstructure that is all one piece. The stock is two halves of plastic screwed to the chassis. All of the checks covered in the other forms of construction apply to this gun equally. There is no special check other than making sure the screws holding the stock halves to the chassis are tight. Any other special inspections at this time would reveal some proprietary construction methods that are not yet finalized.



SEMI-AUTOMATIC HEAVY RIFLE CHECKS

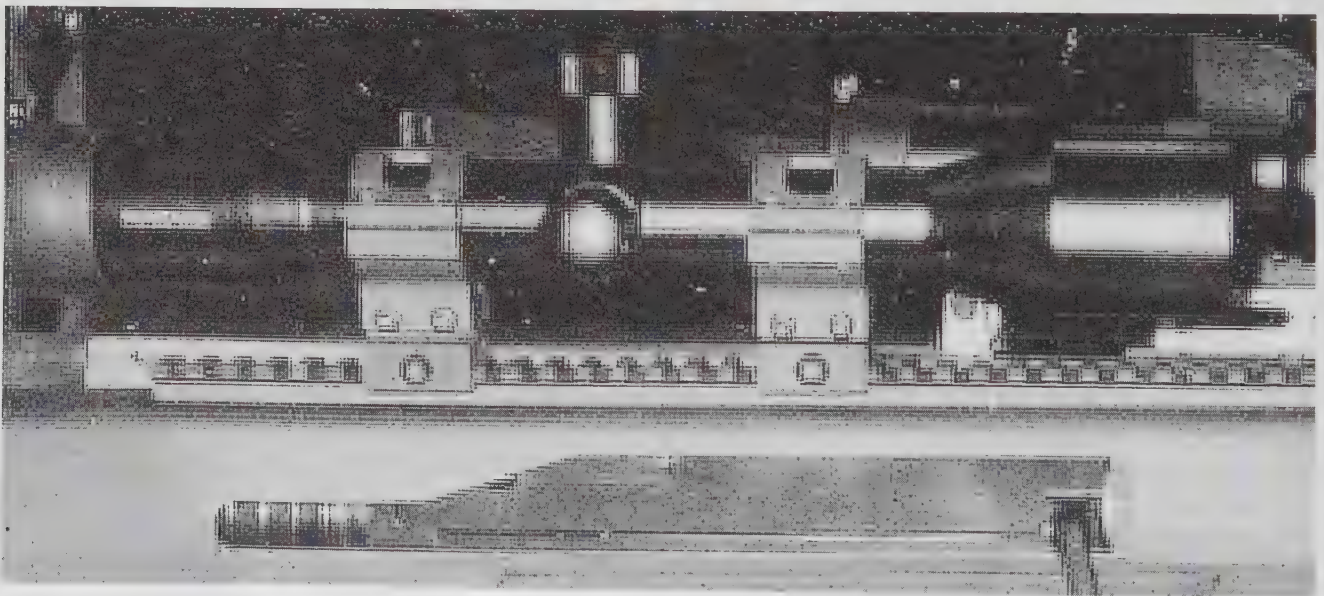
The semi-automatic rifles are represented by the Barrett M82A. While this gun has no similarity to the gas-operated guns, it is by far the most common semi-automatic and represents this class of heavy rifle. This gun has had a lot of exposure to military units and consequently many lessons have been learned. The gun is very simple, but there are some points that need to be carefully looked after. The barrel of the rifle rides fairly loosely in the “receiver” that is made up of an upper and a lower half of steel components. The M82A2 receiver components are made from aluminum. While many of the checks are the same in nature as the previous mentioned rifles, there are different nuances that apply to each of them. The major pre-operational checks are covered in the Barrett Manufacturing manual. The following are lessons learned that are NOT covered in the manual.

- **Receiver Checks.** The two halves of the receiver are held in place by two tension loaded spring ball pins. These pins DO NOT bear load under recoil. The recoil bearing is taken up the by steel blocks that are part of the forward barrel ring and at the rear of the receiver assembly, where a pin protrudes through the upper and lower half of the receivers. There have been a couple of cases where a cartridge fired while the bolt was not locked into the lugs in the barrel seat. There was no injury to the operator although the upper and lower half clearly expanded away from each other. The pins did not fail and the rifle stayed together. Always check for elongated pinholes, misalignment and cracks around the pinholes. If the springs supporting the spring balls in the retaining pins get weak and have little tension, replace them. They are a common item and can be purchased at any bolt or screw shop.
- **Buffer Damage.** The large coil spring in the rear of the gun behind the bolt carrier is a fairly loose spring. Much of the recoil energy is absorbed in the short stroke made by the barrel. As the large diameter springs are worn out, the buffer will show signs of damage. You will find little pieces of this buffer coming off and visual compression damage to the buffer itself. When this starts to occur, replace the spring and the buffer. Another cause of damage on this spring and buffer is the wearout of the two forward springs that make up the C-clip barrel retainer in the front of the receiver.
- **Forward C-clip and springs.** When the barrel is slid forward into place, the C-clip with two attached springs is slid into an engagement slot on the barrel itself. This holds the barrel forward and is the basis for the first stage of the recoil process. There are two 1/2-inch diameter springs that do this. When buffer damage starts to show up, it is recommended that all springs be replaced, the two in the front and the large coil spring in the rear. There is extreme tension on this C-clip as the springs are stretched back and the clip is slid into place. Some damage always occurs to this very hard plastic clip. As the engaging edges are chewed away by being slid into place, less and less of the clip actually encounters the critical forward part of the notch in the barrel. Replace this clip as this wear becomes more apparent.
- **Barrett Scope Rings.** The 30mm scope rings that are used on the M82A1 rifles are similar in construction, but are NOT the Mark IV rings from Leupold & Stevens. The rings are provided by Barrett Manufacturing and are made to their specifications. When the Swarovski scopes were removed by

operators to replace them with L&S Mark IV, M- I scopes, deep scratches were noticed on the tubes of the scope—in several cases, these were considered gouges. The rings were examined and the edges of the inner diameter of the rings looked as though they had been drilled through and left in the rough. This can cause the scope to rest on a ragged shard of steel and become damaged. There is little contact through the rest of the ring on that half of the ring containing this protrusion. The scope not only has a deep gouge in it, but a great deal of stress is input into the scope tube as the cap screws are tightened when installing the new scope. This is easily repaired by taking a large diameter round file and removing this metal. You should be able to take your fingernail, drag it across the inner diameter of the ring, and not have it snag as it slides over the edge of the inner diameter. It is then suggested that a 30mm steel bar and some lapping compound should be inserted into the rings and the inner diameter of the rings should be lapped in. The claws that bear directly on the 45 degree flats of the scope base have had some of the same steel tool marks that keep the engagement claws from correctly engaging the scope base. While the gun may zero and group, it will NOT repeat that zero when the scope is taken off. One of the first indicators of this is shots going very high or low on the target, indicating extra material on the forward or rear claws on the rings. The new model rings have yet to be fielded and evaluated. First impression though is that the adjustable angle rings must be solidly secured so that there is no shift in the rings after the heavy recoiling and vibrations set up by these rifles.

- The Scope Base. The scope base is machined out of steel in the Picatinny rail style, but with differing dimensions on the cross-slots on the base. It is held to a permanently attached sub-base (that is welded to the receiver) by 4 bolts with self-locking nuts under the subbase. While self-locking nuts usually work fine, they still come loose. There have been several cases of these screws coming loose after the gun has some rounds put through it. It is recommended that the bolts be removed and replaced using new self-locking nuts and #271 Loctite.

When you have completed the above checks, you are pretty much at the mercy of the rifle. If the front receiver ring is getting sloppy or there is too much movement in the rear barrel ring inside the receiver, it's time to get a new tube. Ken Johnson of K&P Barrels will re-barrel the rifle with one of his barrels. He uses a



The new model scope rings from Barrett. These have an adjustable angle as can be seen by the two screws above the mounting screws at the bottom of each ring.

tighter clearance on the front ring and the rear inner specifications to get more precision out of the gun. With one of his barrels, the guns do fairly well in the Fifty Caliber Shooter's Association matches that are shot at 1,000 yards.

BARREL BREAK-IN PROCEDURES

A subject that has received a lot of attention these past couple of years in the sniper community is the process of breaking-in a barrel. In the Special Forces Groups (at least at Fort Lewis) this process has started to catch on very well. Unfortunately, many operators are unaware of this process. Even worse are the shooters who are aware of this need, but are not given the time to do it correctly. The result? Rifles that are not shooting as well as they could, barrels that foul faster, and guns that cannot hold their accuracy over a long training session and wear out sooner.

The Benchrest shooting community has always placed a great deal of emphasis on this matter. The shooters that I have met at National Match competitions were always talking about "breaking-in their new match barrel." Breaking-in a barrel has many payoffs, although it is a time-consuming process. There are different methods advised by many different barrel manufacturers. The one recommended here has been used on many different barrel makes and has worked beautifully. For the materials, refer to the section on cleaning the SWS in this chapter. You don't need any match ammunition. All you need for ammo is a load in which a jacketed bullet will leave the bore of the gun. I recommend that you don't even use a target, or you will be tempted to group the rifle. Wait out the break-in process. Here is the procedure:

- After receiving the newly barreled rifle, thoroughly clean the barrel. After a cleaning I always make one pass down the bore with a patch wetted with a little WD-40.
- Fire one round out of the gun.
- Insert the bore guide and brush the bore out with Shooter's Choice. Only 8 to 10 strokes are needed in this process.
- Run 3 or 4 dry patches through the bore to clean and dry it.
- Put a few drops of Sweet's 762 Copper Solvent on a patch, push this down the bore, and remove the patch after one pass.
- Allow the solvent to work for a couple of minutes.
- Spray some WD-40 on a patch and push the patch down the bore to chase out the Sweet's 762 and follow this patch with several dry ones.
- Smear some JB Bore Cleaning Compound on a patch and wrap this patch around the jag. Push the rod down the bore but do not let the patch go all the way through the barrel. Scrub the rod back and forth in the barrel for 10-12 passes and push the patch out of the end.
- Spray WD-40 on a patch and push this patch through the bore. Repeat this 3 or 4 times until all of the gray JB matter is out of the bore.
- Run dry patches through the bore until the bore is clean and dry.
- Fire another round and repeat the above 10 steps.

It is recommended that you do this single-shot-and-clean process for the first thirty (30) rounds. I know it sounds like a long time and it is. After you have done single shots, it is OK to put a target downrange and shoot 5-round groups. Until you have 60 rounds out of the gun, clean and JB the barrel every 5-round group. The long-term results are well worth the work. You will also notice that there will much less, if any, copper fouling in the barrel.

CLEANING MATERIALS

Here is a list of the needed cleaning materials for maintaining and cleaning precision rifles. It is recommended that you use a fishing tackle box and build a maintenance kit for your rifle.

- Powder Solvent such as Shooters Choice or Hoppes #9. Copper remover such as Sweet's 7.62.
- .50-caliber copper bore brush. Do not use the brush with Sweet's as it will ruin the brush.
- Bore Guide
- Rifle grease such as Tetra Gun grease, Shooter's Choice Grease, or Molly D grease
- A non-embedding bore cleaning compound such as JB. This is a powdered diamond abrasive cleaning compound which comes as a paste that finishes the powder and copper removal process and polishes the bore.
- Pipe cleaners
- Cotton swabs
- Bore jag made of brass. The brass jag is softer than the barrel's steel, so no damage should occur.
- WD-40
- .50-caliber bore patches. The military patches are excellent and cheap.
- Carburetor cleaner. Do not use foam brands.
- Standard weapons cleaning brush or toothbrush
- Rags

CLEANING THE BOLT-ACTION HEAVY RIFLES

WARNING: Exceptional care must be taken to ensure that the crown, or the end of the bore, is not in any way damaged during the cleaning process.

We will begin explaining the cleaning process for each of the two major types of rifles at the point in which the rifle is fieldstripped and disassembled for cleaning.

- Insert a bore guide into the action of the rifle.
- Insert a cleaning rod with the bore brush attached into the bore guide. Soak the brush with powder solvent (Shooter's Choice). Now push the rod through the bore. The copper of the bore brush will not harm the rifle's bore. Scrub the bore with 20 or 30 passes adding solvent to the brush every 10 passes or so. Allow the solvent to remain in the bore about 10 minutes to attack the fouling the brush doesn't reach.

WARNING: Do not allow any solvent to leak into the weapon's trigger group, as it will promote rust.

- Clean the bolt using powder solvent (Shooter's Choice) and scrub the bolt lugs and bolt face with a toothbrush.
- Brush the bore again using the bore brush and powder solvent.
- Using the rod with the bore jag attached, run patches with powder solvent through the bore until it is relatively clean and then dry the bore with another patch.
- Saturate a patch with Sweet's 7.62 and push the rod to within one inch of the crown, or end of the bore.
- Fill the last inch of the bore with Sweet's 7.62 and pull the rod toward the chamber. When you reach the throat, or end of the chamber, stop. Allow a few minutes for the Sweet's 7.62 to chemically dissolve the copper jacketing deposits. This method allows for a thick pasting of Sweet's to build up in the badly fouled areas. Just pushing a wet patch through the bore does usually not leave enough Sweet's in the barrel.

- Push the dirty patch out of the barrel along with the excess Sweet's. The solvent will turn blue after contact with copper. The excess Sweet's can be recovered provided the bore was absolutely cleaned of powder and powder solvent. This Sweet's is positively charged with dissolved copper and attacks hardened copper in the bore much more aggressively than clean Sweet's.
- After approximately 100 to 400 rounds the bore should be cleaned with a nonembedding bore cleaning compound such as JB. Apply JB sparingly to a patch. Using a scrubbing motion, run the patch through the bore about 10 to 15 times repeatedly. The patch should become black.
- Thoroughly clean the JB out of the bore using a rod, jag, patches, and either powder solvent, WD-40, or carburetor cleaner. Then swab the bore using another patch. The patch should look nearly the same coming out of the bore as it did going in.

WARNING: Any residue of JB bore cleaning compound left in the bore can seriously damage the bore if a bullet is fired through it.

- Clean the chamber using a chamber brush and powder solvent. Dry the chamber using swabs.
- Clean the barrel's recoil lug, which is located in front of the action.
- Clean any portions of the stock that require it with careful attention to the recoil lug slot, the bedding area (if there is one), and the portion of the stock on which the barrel floats. Ensure the stock is free of debris.
- Lubricate the bolt using shooting grease (Tetra gun grease). Lubricate the lugs, the bolt body, and the portion of the bolt where the bolt handle is attached to the bolt body.

The cleaning process is much easier to accomplish while the weapon is still warm from firing.

CLEANING GAS OPERATED HEAVY RIFLES

WARNING: Exceptional care must be taken to ensure that the crown, or the end of the bore, is not in any way damaged during the cleaning process.

- First, insert a bore guide into the chamber. Use the bore guide to hold the upper receiver open, making it easier to clean. There is no need to separate the upper and lower receiver totally to clean the barrel.
- Insert a cleaning rod with the bore brush attached into the bore guide. Soak the brush with powder solvent (Shooter's Choice). Now push the rod through the bore. The copper of the bore brush will not harm the rifle's bore. Scrub the bore with 20 or 30 passes adding solvent to the brush every 10 passes or so. Allow the solvent to remain in the bore about 10 minutes to attack the fouling the brush doesn't reach.

WARNING: Do not allow the any solvent to leak into the weapon's trigger group, as it will promote rust.

- Clean the bolt carrier group using powder solvent (Shooter's Choice) and scrub the bolt lugs and bolt face with a toothbrush.
 - Brush the bore again using the bore brush and powder solvent.
 - Using the rod with the bore jag attached, run patches with powder solvent through the bore until it is relatively clean and then dry the bore with another patch.
- Saturate a patch with Sweet's 7.62 and push the rod to within one inch of the crown, or end of the bore.
- Fill the last inch of the bore with Sweet's 7.62 and pull the rod toward the chamber. When you reach the throat, or end of the chamber, stop. Allow a few minutes for the Sweet's 7.62 to chemically dissolve the copper jacketing deposits.

- Push the dirty patch out of the barrel along with the excess Sweet's. The solvent will turn blue after contact with copper. The excess Sweet's can be recovered provided the bore was absolutely cleaned of powder and powder solvent. This Sweet's is positively positively charged with dissolved copper and attacks hardened copper in the bore much more aggressively than clean Sweet's.

WARNING: Do not allow the copper solvent to leak into the weapon's action as it will promote rust.

- After approximately 100 to 400 rounds the bore should be cleaned with a nonembedding bore cleaning compound such as JB. Apply JB sparingly to a patch. Using a scrubbing motion, run the patch through the bore about 10 to 15 times repeatedly. The patch should become black.
- Thoroughly clean the JB out of the bore using a rod, jag, patches, and either powder solvent, WD-40, or carburetor cleaner. Then swab the bore using another patch. The patch should look nearly the same coming out of the bore as it did going in.

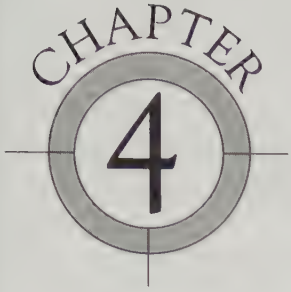
WARNING: Any residue of JB bore cleaning compound left in the bore can seriously damage the bore if a bullet is fired through it.

- Use carburetor cleaner to blow out the gas tube in the upper receiver on gas-operated rifles. You must blow out any Sweet's or JB bore cleaner that is left in the gas tube. If you leave any substance in the tube, it will promote fouling and cause malfunctions.
- Clean the chamber using a chamber brush and powder solvent. Dry the chamber using swabs and carburetor cleaner.
- Clean the upper receiver using a cleaning brush and powder solvent. Dry the upper receiver group using swabs.
- Lubricate the bolt locking lugs using shooting grease (Tetra gun grease).
- Lubricate the lugs, the bolt body, and bolt carrier with CLP or lightweight oil.
- Assemble the weapon lubricating all of the critical points in the operators manual.

The cleaning process is much easier to accomplish while the weapon is still warm from firing.

ADDITIONAL NOTES ON RIFLE CLEANING, CARE, AND MAINTENANCE

You should always contact the rifle manufacturer and get his advice on ways to take care of that particular rifle. The gun builder will always have advice on the best way to take care of his gun. The barrel manufacturer is another good source of information on the care and cleaning of barrels. In discussions with several different manufacturers, they all had additional little bits of information about cleaning and break-in that gave excellent results. They should know—they cut them and built them.



Introduction to the HTI Training Environment

It is usually assumed that any shooter who attends a sniper school and is successful at engaging targets with his assigned sniper weapon system can do the same with a heavy-class rifle. Unfortunately, this has proven to be very untrue. While working as an instructor at the Special Operations Target Interdiction Course at Fort Bragg I began to keep data on the students we trained there. There was a period about 5 weeks into the course where they were introduced to .50-caliber SWS. We had one Daisy Model 600 at that time. It was a very good gun.

At that time (1989) we did not have any data tables yet developed and the data that was on the scope was the same data that was used the class before. You see, the instructors had their fun with the gun by zeroing it and having “off hand” shoots with the gun. We actually stood at the 1,000-yard line and shot the rifle standing off hand. Not a pretty sight. The average class size back then was probably 12 snipers, with a low of 4 and a high of maybe 20. On that special day, we let each sniper shoot the .50-caliber SWS from the 1,000-yard line and a pre-zeroed rifle. We noticed something very interesting. From the batches of snipers that we seen come through, about 2 out of every 10 could shoot the big rifle with any degree of accuracy.

There was a lot of head scratching. Some of the instructors couldn’t shoot the gun very well either. My sniper partner at that time was SFC Randy Lykens. We both used a position that was as neutral as possible with our bodies directly in line with the bore of the gun. We did that because that was the way we shot our “little” guns. As it turns out, that is the way that we teach shooters to shoot the .50-caliber SWS now. Be neutral, don’t muscle the gun and be directly behind it. If you influence that rifle at all, you are likely to miss the target.

The current heavy rifle in the Army inventory is the Barrett Light .50. It is assumed, both by the manufacturer, many snipers, and lots of commanders, that the SOTIC trained sniper can pick up this weapon, load it with issued ammunition, and by placing the correct reticle on the target, simply pull the trigger and hit the target. All of this is expected to happen at a range extending to 2,000 meters. It can be stated that shooting heavy-class rifles requires a level of sophistication that is not currently instructed anywhere in the U.S. military. It was at one time taught at 1st Special Forces Group’s Sniper Locker. The U.S. Navy SEAL sniper training program comes close. Their method is to beat the dog into submission. It works as long as they are shooting

somewhere they have shot before and under the same conditions. What IS required is finesse, sophistication, a good knowledge of ballistics, and the use of the scientific calculator. Notice that I did not mention anywhere any previous formal sniper training. Historical data by this author has proven that previously trained shooters did no better and sometimes worse at HTI methods than did a totally untrained shooter.

Many tests officially done and some unofficially done have come up with determinations that state categorically that one weapon or another is inaccurate. They further state that ammunition is a problem. Well, ammunition is much better now. However, there still persists test data that suggests weapons aren't accurate enough. In a test conducted by NSWC, Crane, January 17, 1995, it was determined that the Barrett M82A1 rifle was not accurate enough to meet standards set by them. NSWC, Crane performs some very good tests and they record their data very well. They also break down shooters by name and how some did compared to others. In the end, by averaging data, they concluded that the test rifles (M82A1s) are not accurate. However, there are some groups in that test that indicate that SOME of the shooters could meet and exceed the standard set for accuracy. Why do you suppose that is?

When an agency does a test of a system, in this case a sniper weapon system, they assume the shooters to be qualified to shoot the systems. That is normally a fair assumption. The Navy and Army special warfare sniper schools are both quite qualified to turn out excellent .308 shooters. However, we are back to the mistaken assumption that a good .308 shooter makes a good .50-caliber shooter. This is not true. Let's examine some of the data from this test. Names will not be included—an ID number will be substituted to protect the identities of the shooters in the test.

The accuracy standard for this test (Page 3, Operational Requirements Document, dated March 1994 and referenced in the Crane test) is 2.0 MOA threshold and 1.5 MOA preferred. As you can see in the table, a number of groups attained that required level of accuracy. The relation of small to large groups is of more interest than the actual size of the groups. When testing light-class rifles, there almost is never the spread in the group sizes that you see with the rifles in this test. There are two possible and separate reasons for that:

First, the rifles aren't consistent enough to shoot accurately to the standard. Second, the shooters aren't trained in the operation of these systems. That isn't the shooter's fault, it lies with the institution that assumes that a shooter who doesn't see any formal training with the heavy rifles can actually employ them accurately and effectively. Credit goes to the Naval Special Warfare Group people who are making a genuine effort in the training department. Listed below are the weapons used in the test and the group results of how they shot. Ranges were at 600 and 1,000 yards.

The rest of this chapter is dedicated to the science and methodology behind training a shooter to handle heavy-class rifles. This involves a training and material analysis of walking a sniper student through the light, medium, and heavy class of rifles. These explanations are based on years of experience in training shooters through these three classes of rifles.

Shooter	Mark 211, MOD-0	M-8 API
Shooter #1		
Large Group	5.49 MOA	6.00 MOA
Small Group	1.77 MOA	1.45 MOA
Shooter #2		
Large Group	5.35	6.20
Small Group	3.07	3.36
Shooter #3		
Large Group	6.76	9.99
Small Group	2.12	2.15
Shooter #4		
Large Group	DNF	6.88
Small Group	DNF	1.88
Shooter #5		
Large Group	DNF	8.55
Small Group	DNF	3.04
Shooter #6		
Large Group	DNF	5.92
Small Group	DNF	1.78
Shooter #7		
Large Group	DNF	8.24
Small Group	DNF	3.42

Gun #1758	6.00	5.49	This rifle only fired four groups in the test. No reason was given in the results as to why this rifle wasn't used more.				<i>Data entries in bold indicate an individual shooter's worst group with that particular rifle.</i>
	3.12	5.35					
Gun #1786	2.32	<i>*1.88</i>	4.09	2.93	5.20	3.87	<i>Data entries in italics indicate an individual shooter's best group with that rifle.</i>
	5.59	3.42	4.22	5.20	4.38	3.27	
	2.32	3.99	4.66	4.65	3.15	2.53	
	2.75	2.04	4.81	3.77	2.48	4.38	
	3.27						
Gun #1790	3.07	3.64	2.31	3.97	4.12	4.41	<i>Look at the individual group sizes. Note that every rifle except #1758 had groups that dipped into the 2 MOA (*) requirement. Look at the previous chart and look at the extreme size of the spread in group size for the shooters.</i>
	6.20	4.54	3.47	4.65	<i>2.12</i>	4.63	
	2.53	2.32	4.46	9.99	2.77	3.34	
	4.12	<i>*1.78</i>	6.38	5.11	6.22	<i>*1.96</i>	
	2.58	6.88	4.09	5.97	5.27	5.92	
Gun #1792	4.11	3.18	<i>*1.77</i>	<i>*1.45</i>	3.98	<i>*1.88</i>	<i>There is a reason for this other than that the rifles aren't shooting consistently. Sometimes the numbers on a test result don't mean a piece of equipment is at fault.</i>
	3.80	3.50	2.89	4.23	2.69	3.06	
	3.15	4.30	3.63	3.68	4.55	3.79	
	5.01	8.24	4.79	8.55	7.11	4.09	
Gun #1793	3.53	<i>*1.99</i>	3.36	4.57	4.73	4.06	
	5.97	6.76	3.74	5.62	4.14	5.60	
	6.16	4.20	3.04	5.44	4.39	4.81	
	5.27	5.05	4.09	6.57	3.79	5.36	
	3.99						

In June of 1991 a document was issued and distributed throughout Special Operations Command. The subject was a Mission Needs Statement for Family of Sniper Weapons Systems. The statement read: "The program objective for the Family of Sniper Weapons Systems (FSWS) is in response to a requirement to provide Special Operations Forces with a reliable, man-portable, signature free, direct line of sight family of sniper systems for attacking pin point targets from a distance of up to 2500 meters."

In the constraint paragraph #5, the following is stated: "The Family of sniper weapon systems will consist of at least three systems. One system will have a range of 900 meters, one a range of 1,250 meters and one a range of 2,500 meters."

This is an interesting document. Within SOF there have always been .50-caliber rifles that fell into the heavy classification. The major problem is that that rifle was the first weapon introduced into the SOF forces that did not come with any training program. From the very beginning operators were without



Definitely not the way to do it.

training or historical and institutional data on the rifle, its optics, and ammunition. More importantly there was no doctrine or institutional knowledge on the training and employment of these systems. Immediately, ad hoc test programs were initiated. The ammo of that time was absolutely substandard for accuracy concerns. The usual end result was the following statement: "This thing is a piece of shit."

As mentioned earlier, we had at SOTIC at Fort Bragg a .50-caliber rifle of our own. Students were introduced to it. Some loved it, most hated it, yet all were interested in making it work. The only ammunition that we had available was the M-33 Ball round and some M-17 Tracer. Both rounds had horrible accuracy characteristics, we thought. As my partner and I worked with the gun and fired round after round we discovered that big gun didn't like to be told what to do. Muscle it and you would be rewarded with a miss. Pull the gun one way or another and you would again be rewarded with a miss. Fight it too hard to get back up on target and, guess what, another miss. Pull the trigger and let it go bang, take a second to breathe, don't influence the gun, and the reward was a good reasonable group. Hmmm, we thought, very interesting.

We began to believe that the major problem with the system (other than admitted ammo problems) was in the training of the shooter. This big gun wasn't a little gun blown up on a copying machine. It took finesse. The following is an analysis of current sniper training programs as they exist for light-class rifles. Then an analysis and comparison will follow for programs that train shooters out to 1,200 meters (medium guns). Finally, there will be a comparison and analysis for courses that shoot out to a range of 2,000 meters and farther. These are the heavy classes of rifles. There are three areas of training that will be addressed in each section. These are: internal ballistics, external ballistics, and human factors.

THE LIGHT-CLASS RIFLE

Generally, all sniper programs conducted in the free world concentrate on the light-class of sniper weapon systems and training. The is as true at SOTIC as it is at the U.S. Army Sniper School at Fort Benning. Some training is conducted on correcting for MET and ENV conditions. It is usually very generalized, as it is not clearly understood by the personnel teaching it. Indeed at SOTIC, Fort Bragg, NC, correcting for MET and ENV conditions has deteriorated from a highly technical level that actually taught how to deploy your rifle anywhere in the world to a 1 or 2 hour familiarization class on the subject. In reality, light courses in the United States are training personnel how to pass a sniper course taught at that location under the conditions as they exist. For example, hot in July at Fort Bragg, and cold in February at Fort Bragg. The reasons are covered in detail in the external ballistics part of this discussion.



The Accuracy International PM, a light-class sniper rifle.

Internal Ballistics Training

This is defined as all bullet activity that takes place in the gun before the round leaves the muzzle of the barrel. This is not shooter-influenced; it is mechanical only. With the exception of SOTIC at Fort Bragg and the SOTIC detachments of the 1st, 3rd, 5th, and 10th Special Forces Groups, no training is conducted in internal ballistics. It is mentioned here and there that warm cartridges will cause the bullet to strike high and cold cartridges will result in a low impact. How much? That's the key question. SOTIC at 1st SFGA in 1996-1997 (the only years of its short existence) was the only place that taught snipers how to mathematically calculate and correct for ammunition temperature. With the light-class rifles and the shorter ranges involved, this factor only has small meaning. However, with the heavy-class guns, it is absolutely essential that it is determined and corrected for.

Finding and dismantling Soviet and other produced ammunition and using those components in U.S.-made cartridges is also taught at SOTIC and their detachments. Precision loading of cartridges using match bullets and other match components is only taught at U.S. Army SOF sniper schools. However, as of late, this practice has come under fire as officers worry more and more about "an incident" involving personnel and these components. It is predicted that within the year, this practice will cease altogether.

External Ballistics Training

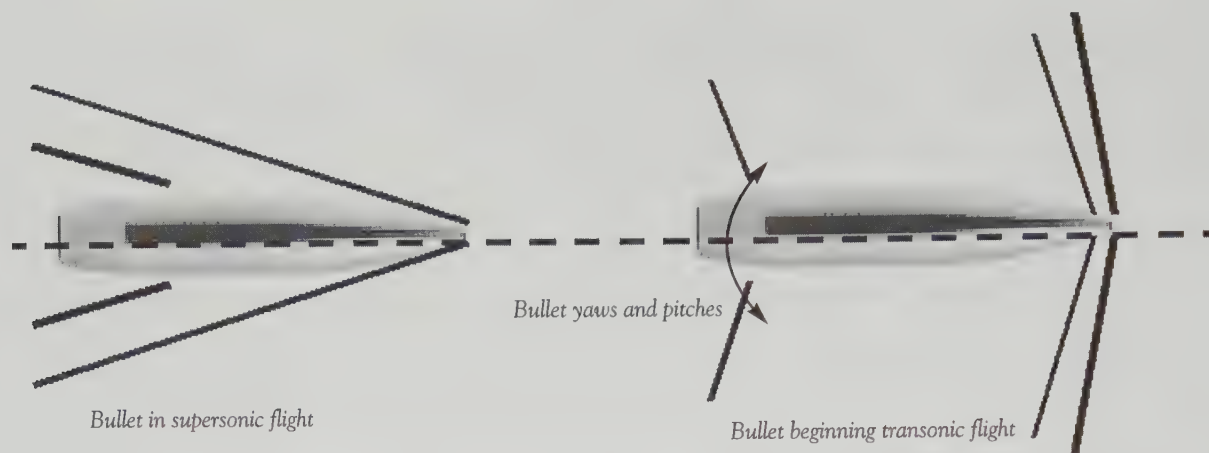
This is defined as the flight of the bullet from the point at which it leaves the muzzle until it impacts with ANY object downrange. It is important to note that this does not mean impact with the target. The factors that are involved in external ballistics are many. They include:

- Barometric pressure
- Air temperature
- Humidity
- Slant range to the target
- Spin-drift corrections

At SOTIC at the 1st SFGA, we trained shooters to correct mathematically for changes in barometric pressure, air temperature, ammunition temperature, spin drift, and the slant range to the target. We train this way so that Special Operations snipers can deploy anywhere in the world in any environmental condition and place effective first-round shots on ranges up to any limitation in the system. The current belief is that shooters can rezero in the new environment. This is a dangerous fallacy. Rezeroing in the new conditions will only work if you rezero at precisely the range and condition in which you will place the shot.

A case in point: At a sniper match conducted by the 10th SFGA at Fort Carson, CO, we deployed two sniper teams. Prior to departure we requested and received a climatology report for this area. This gave us the barometric pressure, temperature, and dominant wind predictions for this area. On arrival these predictions proved to be very accurate. We were provided the opportunity rezero the weapons at 200 meters. We knew that this would only prove that the weapons were mechanically sound after the travel. There were OK. The next day the matches began. At the 500 meter range our sniper teams broke out thermometers and barometers that we procured from the Air Force weather team assigned to the group. The shooters measured the temperature of the ammunition and calculated their corrections based on the MET and ENV conditions. The final correction was down 2.5 MOA, from the original 500 meter setting on the scope. Our two teams cleaned the 500 meter line. We were in the 10 and the "X" ring. All other teams were high in the 7 and 8 rings.

We believe that rezeroing in the new conditions (at ranges up to 300 meters) will only prove that the rifle is mechanically sound. Carlos Hathcock in his famous 2,500 yard shot with a .50-caliber machine gun admitted to a bit of luck in his shot. He was only able to do that shot because he zeroed the gun at that precise point in the same MET and ENV conditions the day prior to shooting his target. By doing that, he built in the



MET and ENV conditions into his zero on the weapon. You can call that a mission specific point zero. All of the military courses mention correcting for environmental conditions, yet none of them explain exactly how to do anything about it. The data that is put out is usually hand-me-down information from open sources that is frequently inaccurate.

Another factor in external ballistics is determining the maximum effective range of a particular sniper weapon system, ammunition, and the shooter. In the current school of thought about military sniping, it is accepted that all targets are within the supersonic range of the rifle. The maximum effective range of the M-24 by the book is 800 meters. Most schools and the SOTIC detachments agree that 600 meters is the maximum range for first-round hits on targets. I would like to offer a new definition of maximum effective range. This is offered because of the ability for shooters to determine the MET and ENV conditions and correct these conditions into MOA adjustments on their scopes. The shooter also has the ability to determine the range at which his bullet will go subsonic in flight.

When the bullet leaves the barrel and is in flight, the supersonic shockwave is approximately 25 degrees to the line of flight. As the bullet slows down this shockwave moves forward until it is almost perpendicular with the nose of the bullet. That occurs just about when the bullet goes back through the sound barrier and is traveling subsonic. When the shockwave is perpendicular to the bullet, the bullet yaws and the tail starts to move around as it fights to get back through the sound barrier again. This causes some displacement in the bullet in comparison to the original line of flight. The bullet actually buffets somewhat as it fights that shockwave. Jet aircraft going from supersonic flight and back to subsonic flight also encounter this buffeting action. The problem is that the bullet is disturbed by this action and becomes unpredictable after transitioning. The Army Match round, the M-852 cartridge has the 168 gr. Sierra Matchking bullet in it. It is an excellent 600 yard cartridge. When fired at 1,000 yards, it consistently hits the target yawing and pitching. This is evident by the elongated holes in the target; sometimes full keyholing occurs (the bullet hits sideways on the target).

Maximum Effective Range is that range at which the selected round of ammunition begins its transition to subsonic flight. This figure can be determined and corrected to the existing MET and ENV conditions and corrections placed on the scope of the rifle. Conditions easily exist to where the bullet begins its transonic flight at ranges farther than under standard atmospheric conditions.

Although the M-852 cartridge is a poor long range performer when compared to the M118 or the newer M118 Improved, some schools have it as their standard round for training. While it is more accurate than the older M118 cartridge at shorter ranges, it falls behind the M118 at ranges past 700 yards.

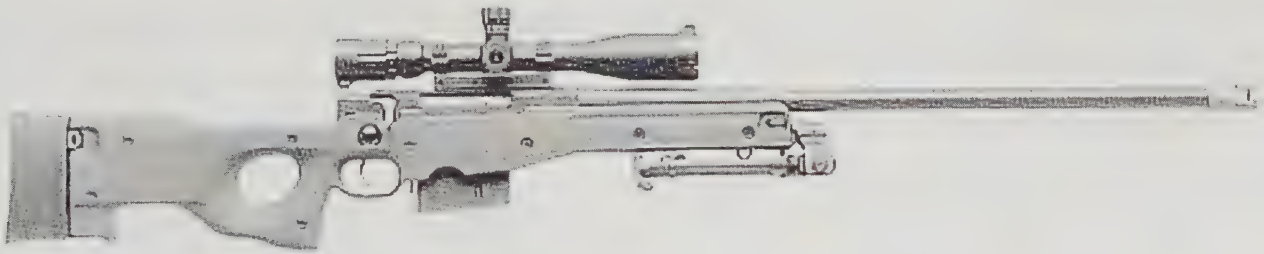
The Human Factor

By default, the standard caliber for light-class rifles the world over is 7.62 x 51mm NATO, or .308 Winchester. This round is small compared to the cartridges of the medium and heavy class. One of the advantages of this is that a student can shoot 100 rounds or more per day in training. SOTIC at Fort Bragg has a solid week of National Match style shooting involving standing, sitting and prone positions. They practice the national match course of fire and shoot the match as a matter of course points. This is all with iron sights that only the M-24 has. Other rifles have irons as backups but they don't equal the precision of the M-24's sight system.

This high round count can add up to some pretty intense training schedules, not to mention some heavy wear and tear on rifles. A student fires an average of 1,400 rounds during a SOTIC Level I course. With an average life of around 8,000-10,000 rounds, the guns get rebarreled about once every year and a half. The human factor that we are talking about here is the factor of the level of punishment and shooter burnout that occurs from shooting the different rifles. Needless to say, a shooter couldn't tolerate 100+ round days with a .300 Winchester Magnum or a .50-caliber rifle. Some talk has been made about converting all of the Army special operations M-24s to .300 Winchester Magnum. That would be a mistake in that a huge portion of the training at the school would have to be trashed because of shooter burnout and weapon wear and tear.

THE MEDIUM-CLASS RIFLE

The current medium-class rifle in Special Operations is the .300 Winchester Magnum. It is type classified as the M-91 and built by NSWC, Crane. The Army has access to these rifles through the JOS center at Lexington, KY. Units can request them and sign them out for up to 90 days. Pure shooters out there right now are scratching their heads. I can feel it. Snipers signing out rifles and then turning them back in? Worldwide? What kind of maintenance can these rifles see? What kind of abuse? Well the weapons seemed quite fine. JOS personnel seem to take good care of them. Snipers who sign them out also take good care of them. The program seems to work quite well.



Accuracy International's .338 Lapua Super Magnum is an example of a medium-class sniper rifle.

The sniper weapons section at NSWC, Crane builds these guns on Remington Model 700 actions. Most of them have Hart barrels and are bedded into a McMillan fully adjustable A-2 stock. Very good system. NSWC, Crane also adds a touch of their own. The recoil lug is of their design with an enlarged lug area that is almost an inch long under the chamber. This block is drilled and tapped and a third bolt is added in front of the floorplate. Three bolts hold this action in the stock instead of the two. All three bolts pass through aluminum pillars between the action and the floorplate. Overall, it is an outstanding rifle. Very, very tough. The document stating the range for the medium class rifles requires a gun that can hit targets to a range of 1,200 meters. With the ammunition intended for this rifle, built by Federal Cartridge Company, the supersonic range is well past 1,200 meters.

Internal Ballistics Training

Federal Cartridge Company builds the round of choice for this rifle to NSWC, Crane specifications. In 1987 a contract was awarded to Federal to produce a .300 Winchester Magnum cartridge for use by the U.S. Navy Special Warfare personnel. It has evolved somewhat and is currently built using Federal Match brass, a Match primer, and a 190 gr. Sierra Matchking bullet. Nominal velocity is 3,000 fps. In Army Special Operations, shooters are trained how to tear apart Soviet ammunition and reload their 7.62mm cases with the Soviet components. They need only have replacement primers. With the advent of the .300 Winchester Magnum and the possible across-the-board replacement for the 7.62mm cartridge, battlefield recovery may not continue in its current state. As usual, Crane did extensive testing and evaluation before deciding on the best bullet and powder combination for their cartridge.

External Ballistics Training

The greatest advantage that the .300 Winchester Magnum has over the 7.62mm is in the area of external ballistics. Simply put, the shooter doesn't have to think as much using this round as he does with the 7.62mm round. The bullet is heavier and faster than the M118 round. At a target engagement range of 1,200 meters, the .300 Winchester Magnum performs stronger than does the 7.62 x 51mm at its maximum effective range of 800 meters. Because of the stated mission of the medium-class rifle, it is desirable to have a load combination that has excellent long range flight characteristics. For sniping this means a bullet that has a low fall angle at the target range of 1,200 meters. Why? The shallower the fall angle, the less the sniper has to have his range determination. Danger space is an important part of sniping. Danger space figures are the numbers the sniper team uses to determine their required accuracy in determining the range to the target. The flatter the trajectory, the less precise their range has to be. We use a danger-space figure based on 2 MOA target size to determine the degree of accuracy required to range and shoot a target.

EXAMPLE: Place a shot anywhere on a 6' tall man. Remember stories about shooting people at 1000 meters?

Danger Space for 7.62x51mm = 69 meters.

Danger Space for .300 Win. Mag. = 109 meters

The figure 69 or 109 meters is the margin or error allowable for engaging a target at 1000 meters. You divide that figure in half (34.5) and you are given a "range bracket" that your range determination must fall in.

965.5 – 1034.5 meters

Both of the above figures would appear to be large enough danger space figures to accurately determine the range to the target. The problem is that hitting a target isn't your goal. Placing a killing shot on that target is the goal.

When you make the size of the target 2 MOA, which is a killing shot on a target, the story is different

DANGER SPACE FIGURES FOR A 2 MOA TARGET AT 1000 METERS

7.62x51mm NATO = 19 meters (990.50-1009.5)

.300 Win Mag = 29 meters (985.25-1014.5)

.338 Lapua Super Mag = 34 meters (983-1017)

The .300 Winchester Magnum is 52.63% more efficient at 1000 meters on a 2 MOA target because of its flatter trajectory. But the Danger Space figure is only 29 meters. Pretty small.

The .338 Lapua Super Mag is 78.94% more effective than 7.62mm and 17.24 more effective than .300 Win Mag.

By the way, don't think that Mil Relation range finding is any good, it's not. Try and Mil a target that's not paper, doing soldier stuff. Very very difficult, almost impossible. Refer to the Chapter on Application of Fire for solutions to these problems.

The above figures leave one scratching his head wondering if ranges can be accurately determined using current U.S. military range-finding methods. There is good reason for head scratching because there is no method in the Army system for determining the range to the target at this precise level of requirement. There is another problem for special operations forces snipers: Because of the advent of these long-range systems and the fact that laser range finders are considered the norm for sniping, a countermeasure was developed. Actually, it is a spin-off of another countermeasure. Laser sensors are now available on the market. They are not expensive. High value targets can be covered by a network of laser sensors that would alert security forces if a target were being hit by a range finder or a laser target designator. These active systems could bring a smoking halt to sniper operations.

Mil relation works fine for targets in school; E-shaped silhouettes are nailed to sticks and buried in the ground. They do a fine job of not moving, however, much to the chagrin of a student or two, they blend in. Well, soldiers and sniper targets do not sit still and they sometimes blend in very well too. The combination of that can be a little difficult to mil in and obtain something of an accurate range.

The .300 Winchester Magnum handles MET and ENV changes much better than the 7.62 x 51mm round. The effects of MET and ENV can be ignored (except for ammo temp) until you are shooting past 400 meters for the 7.62 x 51mm NATO round. For the .300 Winchester Magnum, these effects can be ignored until you are shooting past 700 meters.

The medium-class rifle is designed for shooting to a range of 1,200 meters (standard atmospheric conditions). Sometimes you won't be able to shoot 1,200 meters, other times you will be able to shoot farther than 1,200 meters. Under SAC the military .300 Winchester Magnum round goes subsonic at about 1,500 yards.

The Human Factor

All students firing the .300 Winchester Magnum for the first time comment on the recoil of the weapon. Some shooters take extensive "gun time" to get used to the recoil before they are as effective with the bigger gun as with their 7.62 x 51mm NATO guns. Initially this may be a problem, but, as with the .308 guns, this goes away with gun time and practice. Training the shooters to concentrate on the alignment of the sights and pulling the trigger helps. Iron sight shooting is also an excellent tool for breaking a shooter of flinching from recoil. Good muzzle brakes, such as the one on the Accuracy International .338 Lapua Super Magnum, make a big difference. Full suppressors can also be a great help for the shooter and the tactical situation.



THE HEAVY-CLASS RIFLE

The heavy-class rifle is where the majority of the training shortfalls occur. With the exception of the U.S. Naval Special Warfare people there is NO formal training course for these rifles. The schools do have the guns and students do shoot them. They do not actually train the personnel on how to really employ them. It's not their fault—nothing was ever developed on their use and employment. It has always been assumed that a good M-24, M-40A1, or M-86 shooter can simply pick up the .50-caliber rifle and employ it.

This is simply not the case. Indeed, the Explosive Ordinance Disposal (EOD) units in the U.S. military have supposedly used the .50-caliber rifle to detonate mines and other explosive devices. I have had EOD personnel for students in HTI courses who said that rounds were simply shot until something was hit. I asked, "How many rounds?" The reply was "Sometimes dozens." Not good.

The Heavy Sniper Rifle Operational Requirements Document, dated, March 1994, states that engagements up to 1,500 meters are the maximum expected range. Shooting at this range requires some very sophisticated mathematics to correct for the MET and ENV conditions. To ignore these calculations could easily result in miss after miss. It has happened time and time again. OK, let's examine the three factors affecting heavy-class rifle shooting.

Internal Ballistics Training

The subject of internal ballistics training is a bit more complex with heavy rifles. The major reason is that all of the rifles built in the heavy class are based on rounds of ammunition built for heavy machine guns. These include the Browning .50-caliber, Soviet DShK .51 caliber (The Diska), the Soviet 14.5mm KPV heavy machine gun and some others. It is interesting to note that the Soviets built the first heavy-class rifle in the PTRD anti-tank rifle. The 14.5 mm is equivalent to .57 caliber. Heavy machine guns all have different types of ammunition for different purposes. Ball ammunition for training, Armor Piercing ammunition for defeating armor and then variations on these two types. In the U.S. inventory, there are also several different .50-caliber cartridges:

- M-33 Ball. Until 1992, not very accurate.
- M-17 Tracer. The tracer shot for M-17 Ball. They two were commonly linked together. Linked 4:1.
- M-8 Armor Piercing Incendiary. This round is available in 10-round boxes for the purpose of special linking customized belts. Reasonably accurate out of .50-caliber rifles.
- M-20 Armor Piercing Incendiary, Tracer. This is the tracer shot for M-8. The two were commonly linked together.
- M-903 Saboted Light Armor Piercing. 350 grain tungsten steel penetrator round for the .50-caliber BMG. Requires a totally different twist for the standard match barrels used
- M-933 SLAP Tracer. This is the tracer shot for the M-903 round.
- Mark 211, Mod-0. This is the round developed for and adopted by the U.S. Navy Special Warfare people. It is referred to as Greentip.

The selection of different cartridges makes the shooting for a heavy-class sniper a little more difficult. All bullets have a little different ballistic co-efficient. This is because of differences in sectional density, weight and bullet design. They all have a slightly different specific gravity, which means the rifle barrel is optimally twisted for one of the above bullets and is only a compromise for the rest. They all have different subsonic transition ranges.

Part of the internal ballistics training for the sniper is the correct selection of a round based on his mission requirements. Some targets may require engagement by an explosive projectile, while for others it is best for a slug engagement where there is no pyrotechnic effect. The sniper may select a magazine of mixed cartridges. He must keep in mind that the lowest performance cartridge is the round determining his best engagement range. He wouldn't want a tracer shot to go supersonic all the way to the target and only have the killing shot go subsonic and destabilize short of the target. Once the internal ballistics solutions is taken care of by selecting the right projectile(s), the problem then becomes one of MET and ENV conditions.

External Ballistics Training

As with the other two fields of sniping (light and medium class), the subject of external ballistics is not much mentioned in the heavy rifle category where training is concerned. Why not? There is no formal training



Hard-Target Interdiction, January 1996, 1st SFGA in Yakima, WA.

program for these guns anyway. This subject is the most ignored and probably accounts for over 90 percent of the misses that occur with the heavy class guns when shooting at extreme ranges. In the following paragraphs the subject of external ballistics training will be broken down into major categories and further discussed. You have two major functional areas when dealing with external ballistics. These two areas have to be measured, assessed and, if necessary, mathematically corrected for. These corrections must be placed on the telescopic sight on the rifle. Notice earlier that I said “extreme ranges.” I am not talking about the urban environment where the shooter is killing bad guys by shooting through walls. These corrections do not have

any effect on the rifle when shooting only 400 or 500 yards. (Although the temperature of the ammunition does come in to play.)

The rest of this section can be read as a lead-in to Chapter 6, “Determining and Correcting for Meteorological and Environmental Conditions.” The two functional areas that effect external ballistics are meteorological (MET) and environmental (ENV). Meteorological effects are those conditions that occur in the atmosphere that affects the flight of the bullet. Environmental effects are those conditions on the grounds that have an influence on the flight of the bullet. By category, these conditions break down as follows:

EFFECTS OF METEOROLOGY

General

When this subject is taught in a formal course, the class is called “Correcting for Meteorological Conditions.” Students are taught about the major MET conditions and how they affect the projectile in flight. At SOTIC, 1st SFGA’s light rifle course, we trained the snipers to be able to deploy anywhere in the world. They are taught that rezeroing in the new target area will do nothing for them unless they zero the rifle at the exact expected engagement range under exactly the same MET and ENV conditions that they expect to engage the target with. Obviously, this is impossible. The range could be easily duplicated so that rehearsal shots can be done, but there is no way to create the MET and ENV conditions because they are somewhat unpredictable. Rezeroing in the new environment only proves that the weapon is mechanically sound and that scopes, bases, rings and numerous other things haven’t been disturbed. Yes, it should be done if possible, but realize it only proves that the gun hasn’t been damaged during movement.

Corrections for Barometric Pressure (BP)

The general rule is, when the pressure is up, bring your sights down; pressure down, bring your sights up. But how much is the right amount? Good question. It has been asked by many sniper students and was the sole reason for this endeavor that began years ago and is culminating in this book. Correcting for barometric pressure does two things at once. It corrects the elevation setting for new barometric pressure as it occurs at

the gun position and it automatically corrects for altitudes above sea level.

The MET conditions are changing all the time. Barometric pressure fluctuates many times throughout the day and night. If you have Internet access, check the local weather and they will show the BP and if it's going up or down. Track these changes over a 24-hour period. Those fluctuations frequently add up to a miss at longer ranges if they are not corrected for. When a sniper team occupies a position, they initially correct for all MET and ENV conditions. Correcting the initial setting for slant range usually won't change throughout the mission. However, barometric pressure and air temperature will change as the surface of the earth heats up and cools down. Sniper teams must constantly measure the MET conditions and place those corrections on their sights as time passes.

As the sniper team goes higher in altitude, their pressure normally will go down. The team carries instruments that can determine the barometric pressure. If these instruments get damaged the team can go to a standard set of tables that gives them correction data for barometric pressure and air temperatures at given altitudes. These are agreed-upon standards and must only be used when no other means of determining the conditions exist.

Corrections for Air Temperature

Air temperature changes constantly. The general rule for air temperature is: temperature up, sights down; temperature down, sights up. Colder air is thicker and causes more resistance to the bullet in flight. Additionally, colder winds blow a bullet more than do hotter winds. Don't think it makes a difference? Think again.

The most easily forgotten thing about air temperature is how much that change in air temperature affects how much the bullet is pushed by a crosswind. Granted, a lot of this doesn't apply too much when shooting only 500 or 600 yards with a .308 or other rifle. That is true. But we're not learning about shooting those short ranges. We are talking about shooting in excess of a mile. Everything must be accounted for and corrected if necessary.

Corrections to the Sights for Ammunition Temperature

Normally, ammunition temperature would be considered internal ballistics. But because the

EXAMPLE: Range = 1200 meters Initial Sight Setting = 49.25 MOA

Slant Range = 1128 meters New Sight Setting = 44.50 MOA

Measured Barometric Pressure = 25.46 in. Hg.

Standard Barometric Pressure = 29.53 in. Hg.

Change in Barometric Pressure = 4.07 in Hg.

Effect on Elevation Sight Setting = -4.75 Minutes of Angle down on sight

New Sight Setting = 39.75 MOA Sight Setting

Note the large difference between the initial sight setting of **49.25 MOA** and the current sight setting of **39.75 MOA**. This is a difference of **9.50 MOA** or a total miss of **128.25 inches high** at the range of 1200 meters.

EXAMPLE: Altitude = 7000' ASL. Standard Temp. = 34.0 degrees F.

February 1996, Ft. Carson, Colorado actual air temp. = 60 degrees F.

MEASURED AIR TEMPERATURE = 70 Degrees F.

Standard Air Temperature = 59.0 degrees F.

Change in Air Temperature = +11.0 degrees F.

Corrected from previous sight setting of = 39.75 MOA

New Sight Setting = 39.25 MOA

Effect on Elevation Sight Setting = -0.50 Minutes of Angle down on sight

In the above example, we brought the sight setting down an additional 0.50 minute of angle for the difference in air temperature. In this example the change is small. On the ground, you cannot know that the change will be small or large, or if it can be ignored until the calculation is made.

EXAMPLE: 1500 Meter Shot with Mk211, Mod-0 Greentip

8 MPH wind 90 degrees to flight of bullet, 40 degrees Air Temp.

BULLET IS DEFLECTED 179” or 10.5 Minutes of Angle

8 MPH wind 90 degrees to flight of bullet, 100 degrees Air Temp.

BULLET IS DEFLECTED 153” or 8.9 Minutes of Angle

**The difference is 1.6 Minutes of Angle or a difference of 26 inches.
A 60 degree air temperature change sound extreme? Ever been to
the desert?**

ambient air temperature affects the temperature of the ammunition, it is listed here under MET conditions.

When ammunition is manufactured, it is at one temperature. When it is shipped, it is at another temperature. Sitting in the ammunition supply point or the store, it is at whatever temperature the inside of those structures is. When it is drawn or purchased it warms up or cools down as it is moved to the range or wherever else it may go. The shooters get their

ammunition and it may go into their pockets, magazines, bags, almost anywhere. The whole time this is happening, it is heating up and cooling down.

The most important temperature in this whole process is the temperature of the ammunition when the trigger is pulled. Why is this important? The standard temperature for ammunition is 70 degrees. But when the powder and primer are cold, they burn slower; when they are hot, they burn faster. When the powder burns faster, the muzzle velocity is higher, and the trajectory of flight is somewhat flatter than it would be with cold ammunition. The data tables for the different types of ammunition have correction factors in them. Roughly speaking, a gain in 50 feet per second in muzzle velocity will cause the bullet to impact 1 MOA high at all ranges. Warmer powder and primer would cause this gain in muzzle velocity.

Calculating Maximum Effective Range

Once the operator has calculated the corrections for all of the MET and ENV conditions, he must determine if the bullet will begin subsonic flight before it hits the target. Using Mark 211, Mod-0 ammunition (High-Explosive, Armor Piercing, Incendiary) the high explosive charge might not detonate against soft-skinned targets once the bullet begins subsonic flight.

There is another reason for calculating the range at which the bullet goes into subsonic flight. The bullet, like aircraft, undergoes some turbulence as it begins its transonic flight. The supersonic shock wave is perpendicular to the nose of the bullet the instant before it breaks the sound barrier and is flying at subsonic speeds. This turbulence will disturb the flight path of the bullet. It may or may not end up flying at the target once it goes subsonic—it is totally unpredictable.

After all calculations are complete for the bullet traveling at supersonic speed when it hits the target, the operator is ready to engage the target. If the bullet is found to be traveling at subsonic speed before it reaches the target, the operator must make one of several decisions:

1. Move closer to the target. The team can calculate how much closer they need to move to ensure the bullet is at supersonic speed at the target.
2. Wait for the MET conditions to improve so the bullet is supersonic at the target. That means they need an increase in air temperature or a decrease in barometric pressure. Another option is to warm up the ammunition to gain some muzzle velocity.
3. Calculate the risk that the range from where the bullet goes subsonic to the target is so short that the expected yaw and pitch in the bullet won't deflect the bullet enough to result in a miss. For example, if the bullet goes subsonic 40 meters short of a 1 meter wide missile body, it is safe to assume that the bullet will hit the target anyway. The type of target and its ability to sustain damage based on shot placement is critical also.

THE ENVIRONMENTAL EFFECTS

General

The subject of environmental effects also crosses over into the subject of application of fire. This mainly has to do with shooting on ground that is sloping up or down. While there are many areas that affect the impact of the bullet, such as danger space and swept space on rising and falling ground, those areas are not part of correcting the sights for MET and ENV conditions. When correcting sights for a first shot, there is only one environmental condition that you must consider:

Corrections for Slant Range to the Target

This correction is a very important one. Ignoring the slant angle to the target can result in such a drastic error that the observer can't see the degree of miss let alone give a correction to the shooter. It is commonly understood that shooting uphill and downhill will cause a vertical change in the impact of the round. When a group of students is asked what that effect is, the common answer is that you will hit low when shooting uphill and high when shooting downhill, or vice-versa. This is not correct. In both situations you will shoot high. With modern instruments you can easily determine the slant angle to the target.

EXAMPLE: Range to Target = 1,200 meters

Slant angle to Target in degrees = 20

New range to target based on gravity = 1,127.63 meters

Using a .50-caliber rifle, had the sniper team not corrected for slant range their shot would have gone 65 inches high above the point of aim. If they failed to adjust for barometric pressure and air temperature, the shot would be off by even more.

The problem of slant range is compounded by the fact that the original range to the target is the actual amount of air between the shooter and the target. The slant range is the range in relation to the amount of gravitational force that the bullet will encounter on the way to the target. If the shooter is higher or lower than the target, the slant range will always be shorter than the true range. It cannot be longer. True range is the long range and slant range will be the short range.

Remember, barometric pressure and air temperature would be corrected for a range of 1,200 meters. That is still the amount of true air between the shooter and the target. Winds are also based on true range. Details on this are in Chapter 7. Things get very complicated when the team is using different projectiles for the same mission. They all have different trajectories and will go subsonic at different ranges.

The Human Factor

At the beginning of this chapter, I related some of my experiences working with the SOTIC detachment at Fort Bragg, NC, and at Fort Lewis, WA. Sniper students at Fort Bragg were put through a very rigorous set of evaluations before they arrived at that part of the course where they got to handle the .50-caliber rifle. At times, these tests have weeded out 60 percent of a class. By the time students put their hands on the .50-caliber rifles they were good at their job. During SOTIC class 03-89, eight shooters were observed firing the Daisy M600 .50-caliber rifle. The SOTIC staff called winds for each of the shooters. Of these eight shooters,

two were able to group the shots into a chest-sized area at 1,000 yards. The six other shooters had bad stringing problems. Some groups were strung vertically and some were strung horizontally.

The Causes

There are several factors that may influence a shooter's ability to shoot and effectively employ heavy-class rifles. This is the consensus of a number of instructors who have been exposed heavily to the big guns and students they instructed in their use.

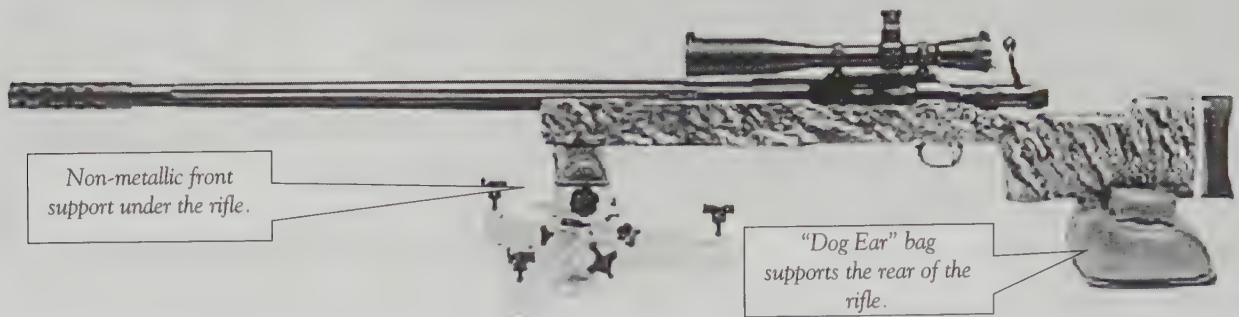
- **Intimidation.** You won't get many shooters to admit it, but a bunch of them are intimidated by the sheer size of this gun and its projectiles. Soldiers and civilians that have shot the .50-caliber machine gun have associated this cartridge with devastating firepower. The ability of the cartridge to fire its bullet through heavy material can easily intimidate.
- **Perceived Recoil.** A .50 caliber without a muzzle brake has a free recoil energy of 124 foot-pounds. In comparison a 7.62mm sniper weapon system has 18 foot-pounds of energy. Fortunately, all of the heavy guns have some type of muzzle brake or suppressor to take most of that recoil off the shoulder. Although the recoil is dampened greatly, the perception that there is great recoil is very intimidating to a new shooter. Instructors have seen shooters wince visibly while pulling the trigger.
- **Overpressure.** The overpressure—the blast wave that comes back against the shooter and observer from the muzzle brake—can be really tough. There is a maximum round count per day that special operations shooters can be exposed to when around these guns. Sandbagging behind the muzzle brake helps a great deal, though. Shooting one of these guns with a sinus block can be very painful. As a result of this overpressure wave, severe flinching and anticipation results in groups that deteriorate rapidly with shot after shot. In tests conducted at the Human Engineering Lab at Aberdeen Proving Grounds the following overpressure levels were determined and established:
 - Maximum safe overpressure level: 150 dB.
 - Level of overpressure felt by the shooter: 180 dB.
 - Standard muzzle brakes on the .50-caliber rifles typically all place about 180 dB. of overpressure energy on the shooter and observer. This also goes for personnel who are close to the side vents on the guns. The effect is like being too close to an explosion with your head out of the foxhole. To counter this effect, the shooter must open his mouth and have effective hearing protection (plugs and hearing muffs).

The Solutions

To effectively fire the .50 Caliber SWS, the shooter must totally accept the overpressures and the discomfort a weapon may cause. Complete and total follow-through is necessary. The shooter must pull the trigger on the rifle without influencing the lay of the gun in any way. Shooters are trained to do this when firing a rifle anyway. However, snipers and hunters all know that you have to move the gun to engage a target. Light and medium class snipers have to move the gun rapidly to engage snaps (human or paper targets that expose themselves for only a few seconds) and movers (moving targets). Sniping in a conventional military environment may require a rapid shift from target to target. This cannot be done with heavy-class guns with large muzzle brakes.

Why? Part of the problem exists with the large bore, long barrel and the muzzle brake. The very device that keeps recoil down causes problems. Hypothetical situation: the shooter is aiming his .50-caliber SWS at a target 1,500 meters away. Because of a little position problem he muscles the gun onto the target. He does this by pulling the rifle to the right a little to put the crosshair on his desired point of impact. He pulls the trigger. The bullet begins accelerating down the barrel and exits at about 2,850 fps. The cold air in front of that bullet is going through the muzzle brake the same way that the hot gas is supposed to go and reduce the recoil.

Granted, not all of the cold air will go through the vents on the side of the brake. Some will go out of the



McMillan Benchrest .50 caliber rifle. Example of totally isolated system. Only shooter input is pulling the trigger.

Without a doubt, the shooter in this picture is muscling the gun. It is an excellent example of poor technique. In his defense, he's probably not a trained shooter, but this is a good example of how not to do it.



hole in the end of the brake. When the cold air goes through the vents, the rifle is pulled away from the shoulder. It is supposed to do that, but not before the bullet leaves the barrel. The result is that the gun is pulled even more in the direction of the shooter's muscling action. This pulls the gun off target in the direction he is pulling the rifle. Result: The shot goes wide to the right; the same direction he was muscling the gun in the first place. Shooters cannot influence the lay of the rifle—they must "neutrally" pull the trigger.

Follow-through, or lack of it, with the big guns causes problems too—much the same way as it causes problems with light and medium guns. There are some solutions to the problem of dealing with muzzle-brake guns. The use of full suppressors on the big guns goes along way toward relieving the shooter of some recoil, blast overpressure, and the tremendous noise from the gun. When we proposed suppressors for sniper weapon systems in Army Special Operations we were met with so much resistance from higher commanders that we had to change the focus of what the cans were intended to do. These days within Army special operations the mention of silencers makes some of them wince. That's too spooky, they say. So we bypassed conventional wisdom with some unconventional wisdom. We said that we needed a device that did three things, and in the order of importance these things were:

- Position Suppression Detection. The suppressors will lessen the otherwise tremendous blast that takes place with a conventional muzzle brake. The conventional brakes vent cold air, then hot gasses that



The Barrett M-95 with AWC turbodyne suppressor.

disturb the ground around the shooter with a large blast of dirt, dust, sticks, and leaves. The can-type suppressor directs all of the blast in a narrow cone downrange.

- Recoil Suppression. Can type suppressors are more effective muzzle brakes than are the open-type muzzle brakes. By totally reducing recoil, overpressure and some very intimidating blast, the shooter's training process is likely to be much more effective. Shooters will learn how to employ the rifle, not how to ignore all of the blast and noise associated with the guns.
- Noise Suppression. It has been argued that a sniper rifle already does suppress sound. Theoretically, it is true that the target is supposed to be far enough away not to hear the rifle, or if anything is audible the noise is so degraded that detection of their position is impossible. That is the argument of non-snipers. This also does not address the problem of security forces that may be closer to the shooters than the target itself. This is especially true for conventional shooters. A good sound suppressor is security for the team. I don't know a sniper around that wouldn't use a can if he had one.

Counterarguments from commanders and officers higher up on the chain of command included statements like "suppressors will degrade your accuracy," "we aren't spooks, we don't need to be quiet," or "they lose too much muzzle velocity." Wrong, wrong, and wrong again. Those arguments may have all been true about 30 years or so ago. Not true anymore. Another spin-off advantage is that the observer's job is much easier with a suppressor. Open muzzle brakes often vent the gasses directly in front of the spotting scope. This totally disrupts the air that the observer is looking through to find the trace of the bullet going downrange. Without that trace, corrections may be impossible

Range Determination Problems

Range determination problems associated with extreme range shooting are the biggest hurdle for a heavy-class shooter. When fired at targets 1,600+ meters away, the bullet starts to get a pretty steep fall angle to it. Depending on the size of the target or the critical component of that target, a very precise range determination is absolutely essential. Unlike in many range training situations, firing extra rounds to find the range is tactically unsound and very hazardous to the team. Laser range finders are many times not accurate enough, or they're not stabilized well enough to get a good laser spot range.

The reason that long-range unknown distance shooters have to know the range as precisely as possible is because of danger space. This subject is covered in depth in Chapters 8 and 9. For now remember that danger space is a figure that long-distance snipers use as a yardstick for the degree of accuracy required in their range

DANGER SPACE OF SELECTED TARGET SIZES (METERS) MK-211, MOD-0

RANGE	1M	2M	3M	4M	5M	6M	7M	8M	9M	10M	11M	12M	13M	14M	15M
500M	500														
600M	600														
700M	209	700													
800M	159	234	800												
900M	120	175	900												
1000M	96	137	219	1000											
1100M	76	108	168	233	1100										
1200M	68	96	149	206	1200										
1300M	50	70	108	147	188	231	275	1300							
1400M	41	58	88	120	152	186	221	257	294	1400					
1500M	34	48	73	98	125	152	180	208	237	267	298	1500			
1600M	29	40	61	83	105	127	150	174	197	222	247	272	298	324	1600

DANGER SPACE IN THIS ZONE IS REPRESENTED BY THE RANGE TO THE TARGET. MAXIMUM ORDINATE DOES NOT EXCEED THE HEIGHT OF THE TARGET. **THIS IS REFERRED TO AS THE DANGER RANGE.**

In this example, the sniper team has a material target that is 4 meters tall. After getting a course range estimation of 1500 meters (map, GPS offset, MIL etc.) They refer to the above table and find that they have to be within a 98 meter bracket to put a round *anywhere* on that target.

However, if the critical part of that target is only 1 Meter high, they have to be within a 34 meter bracket on their range determination.

estimation. Getting a course range estimation isn't difficult. With this course determination and the size of the target, the shooter can refer to a section in the data tables and get a danger-space figure. See the example below.

Targets that are very large and that cannot sustain any hit on them anywhere (i.e. ballistic missiles) are easier to range. The mil relation formula works OK for these large and immobile targets. However, if you are engaging a critical component or using the heavy-class gun for an extreme range anti-personnel shot, mil relation is worthless.

A Solution

Conventional methods of range determination are mil relation, appearance of size of objects, laser range finders, 100 meter unit of measure, and coarse triangulation. (Below is an example of how much error can be induced by using mil relation and the well-thought-of Mil Dot reticle for range finding.) Much talk is made of laser range finders, but they function on batteries, which fail, and they are subject to errors because of meteorological conditions (such as fog, snow, and rain). They are also difficult to stabilize and much user error has happened because of this.

At SOTIC, 1st SFGA, the use of a theodolite was pioneered for range determination. By simply reading the height of a target in degrees, minutes, and seconds and then using a triangulation



Theodolites, used for range determination, are designed to withstand environmental challenges.

Example: Range Determination Using the Mil Relation formula.
TARGET: 22-1C, SCUD-B Ballistic Missile = 11.5 Meters Tall

Mil Relation: Target Milled at 5.0 mils / Range = 2300 meters.
Target Milled at 4.75 mils / Range = 2421 meters.

The difference in the two answers reflects the common error in using mil relation methods. That ¼ Mil mistake is a difference in the range of 121 meters. This can result in a miss on that target, as big as it is.

Same Target Using a THEODOLITE

1st Reading = Vertical Deflection of 16' 30". Range = 2395 meters.
2nd Reading = Vertical Deflection of 16' 45". Range = 2360 meters.
3rd Reading = Vertical Deflection of 16' 37". Range = 2379 meters.

In this example, with a theodolite capable of a 6 second level of accuracy, a 15 second error is common. The change in the range is only 35 meters.

The danger space for this particular missile target using Green tip ammunition is about 106 meters. Split this figure in half (53 meters) and the error of 35 meters would not result in a miss.

formula, extremely accurate ranges can be determined. This can be done on some very small parts. A theodolite has a very precise measuring system. More details are covered in Chapter 7, which deals with range determination.

The theodolite is a rugged instrument designed to withstand extreme weather environments. Some theodolites are capable of reading to 1 second of arc. That's .05625 of a mil. Very precise. Compare this to the famous Mil Dot reticle and that mil sounds very large suddenly. One second of arc at 1,500 meters is .28417 inches. One mil at 1,500 meters is 59 inches. One degree equals 3,540 inches.

Using the known size of the target, manuals of these targets, and the theodolite, extremely accurate ranges can be determined.

Theodolites have extremely powerful and fine optics. They easily replace any current-issue spotting scope in quality. The combined weight of a laser range finder and a spotting scope is over 10 pounds. A theodolite weighs between 5 and 8 pounds depending on the model. Individually they are bulkier, but they take up less space and are lighter than the other two other systems. Their cost is around \$3,000.00 to \$5,000.00 per unit. They can easily be fitted with night-vision systems and a laser pointer slaved to them to designate targets if needed.

Another compelling argument for the theodolite is that it is a passive system. Lasers emit energy that can be easily and cheaply detected.

CHAPTER 5

Sight Adjustment and Zero of the Heavy Rifle

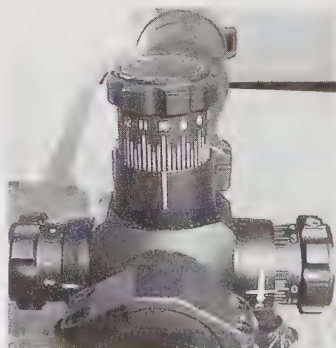
Heavy-class rifles begin in the .50-caliber range and get bigger from there. Not just in the U.S.-inventory but worldwide are numerous system types, manufacturers, and bore sizes. There are a dozen or more builders of .50-caliber rifles in the United States alone. In the world, there are probably two dozen or more that build .50 calibers as well as larger bore rifles. There are Soviet .50 caliber, 14.5mm, 15mm, 20mm, and even some 25mm. With those are any number of “wildcat” guns. These are cases where the large cartridge cases are necked down to accept smaller caliber bullets.

With light-class rifles, the number of optical sight systems and bases by design and type are limited. There are rifle scopes with BDCs (L&S Mark IV, M-3) and then there are scopes with elevation drums that are corrected by MOA clicks (L&S Mark IV, M-1). There are no other system types out there. Swarovski makes one of each system, as does Leupold. Schmidt and Bender and U.S. Optics also have models with both systems. There are models with external adjustments, but these are not BDC type scopes.

There are also two types of bases—those that are parallel with the bore and those that have a taper built into them. In the heavy class, across the board, with U.S. manufacturers, most scope bases have different angles built into that base. The Barrett M82A1 has a 1-degree or 60 MOA base. In almost all of these cases, the operator of the rifle does not know the angle of the base. He simply zeros the gun at a certain range and then “dopes” his gun based on his data book. With rifles capable of shooting over a mile, this is not acceptable. One common practice is to machine just enough angle in the base to allow the gun to shoot just a little bit farther. That is fine except that it still does not establish a clear bottom setting on the scope’s elevation knob. Up 15 MOA from the bottom of 18, 25, or 40 is not acceptable. In tense and high-stress situations snipers can easily get “lost” on that elevation knob. I have seen it time after



Leupold & Stevens Mark IV, M-3.



time. What is needed is a clearly defined bottom end to the elevation knob. What better bottom end than the knob hitting dead bottom and going no further? Then the shooter knows that he is at the starting point for setting his elevation settings. The shooter then can re-index his elevation setting and never look at the knob (something that is hard to do in nighttime tactical environments).

The process of zeroing the heavy rifle begins with knowing exactly how the rifle is built. First the operator must determine the angle of the scope base. He also has to know where the center of travel in his optical sight falls on the elevation drum. For example, with the Leupold & Stevens Mark IV, M-1 16X and 20X, this center of elevation is at +75 MOA on the drum. Even with a base that has one degree of angle in it, there is 15 MOA "lost" at the bottom end of the travel. With elevation settings that do not start at dead bottom, it is easy to get lost on the scope, especially when changing range settings in a hurry.

The method to determine the angle of the base on your rifle is simple. This is provided there is any angle in the base at all. It requires a scientific calculator, a set of calipers, a pen, and paper.

1. Remove the scope base from the action on the rifle.
 2. Measure the overall length of the scope base. If the base is a two piece type, measure the overall length from the rear of the back base to the front of the forward base. 7.0000 inch
 3. Measure the thickness of the base at the front. .35000 inch
 4. Measure the thickness of the base at the rear. .5000 inch
 5. Subtract these two measurements. This difference is critical in the calculation of the base angle. .15000 inch
 6. Enter the difference in Step 5 (.15000) into the calculator and press the divide key. Then enter the length of the base (7.000 inches) and press the = key. .02143 inch
 7. Depending on the type of calculator you have, press the second function key, then the TAN key: **NOTE:** The 1.22758 is in decimal format, it must be converted to degrees, minutes and seconds to actually determine the MOA in the base. Hitting the second function or SHIFT key and locating the DMS key does this. Look at your owner's manual. 1.22758 degrees
or 73.33 MOA
- On Hewlett Packard models you would locate and press the ATAN key.
 - On Texas Instruments, first press the SHIFT key then the TAN key.
 - On other models, it is the SHIFT key or the second function key, then the TAN key.

Now that the degree of angle of the base has been determined, you can continue with the process of establishing a Standard Atmosphere Condition (SAC) zero. If the base on your rifle has NO slant or one that doesn't allow for the elevation settings to start at the bottom, you have a few options. First, all you can do is deal with it. Your "dead bottom" setting is going to be somewhere between mechanical bottom and a turn or two (maybe more) up on the elevation drum. Finally, you can have a base machine precisely to your system.

For example, with the Barrett .50-caliber rifle you have a base that has the beginning of the elevation process starting about 15 minutes up from the bottom of a Leupold & Stevens Mark IV, M-1 or other 1/4 minute scope. This is because the base is 60 minutes and the scope's center of elevation is 75 minutes. If you machine a special base, it is a good idea to leave 5-8 minutes of elevation at the bottom for zeroing the scope.

NOTE: If you are using this formula to determine the angle of the base on actions that have a difference in height from the front of the receiver to the rear of the receiver (as in Remington or Winchester) you must first determine what that difference is. To do this, follow these steps:

1. Remove the action from the stock and with your caliper measure the diameter of the receiver where the front of the scope base is attached, forward of the bolt area. Write this diameter down.
2. Measure the receiver where the scope mounts behind the port of the action. Write that number down. Subtract these two measurements. This is the difference in the height of the forward portion of the receiver and the rear portion. This difference must be subtracted in the formula when determining the angle of the base.

With the base angle established and the type of optical sight that you are using, you can now begin the technical process of zeroing the rifle.

The process used for this method of zero is called the Parallel Bore Zero (PBZ). But before we talk about PBZs, we have to understand the components needed. The author uses a system called the Integrated Shooting System (ISS). The ISS consists of four critical components. These are:

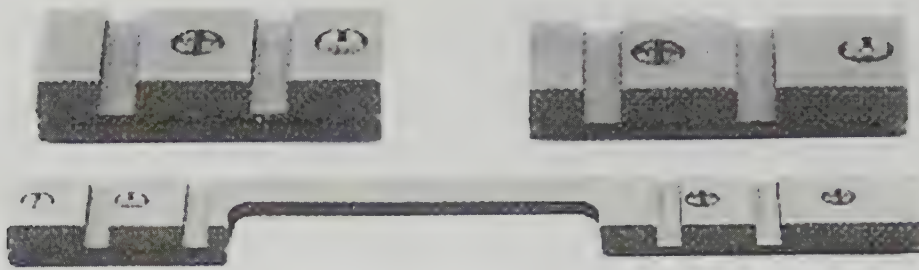
- **The Rifle.** The rifle of course, is built in any caliber. In this case, calibers greater than .50. It is the basis for the shooting system.
- **The Telescopic or Iron Sight.** This is critical because of all the different types of elevation systems that are available. Usually a heavy class rifle will be using a scope with an elevation drum using 1/4 or 1/2 MOA increments. Another important aspect of these scopes is where the mechanical “center” of elevation is on the scopes. With the 16X and 20X Mark IV scopes, it is at 75 MOA. Other scopes have a different center of zero.
- **The Sight Base.** The angle of the sight base is critical. The base on the Army’s M-24 system is parallel to the bore of the barrel. There is no angle to the base at all. The base on the Barrett M82A1 is set at 60 MOA or 1 degree. The U.S. Navy has some .300 Magnums built with parallel bases. The problem is that there are 10X L&S Mark IV, M-1 scopes.

These scopes have a center of zero of 75 MOA. The total range of elevation available is only 90 MOA on 10X scopes. That leaves only 15 MOA available for adjustment. In the past, manufacturers only built bases with enough angle to allow the shooters to use some extra room in the elevation knob. We design the base for the shooter to use ALL of the elevation travel available, with about 5 or 7 minutes for zero procedures at the bottom of the scale.

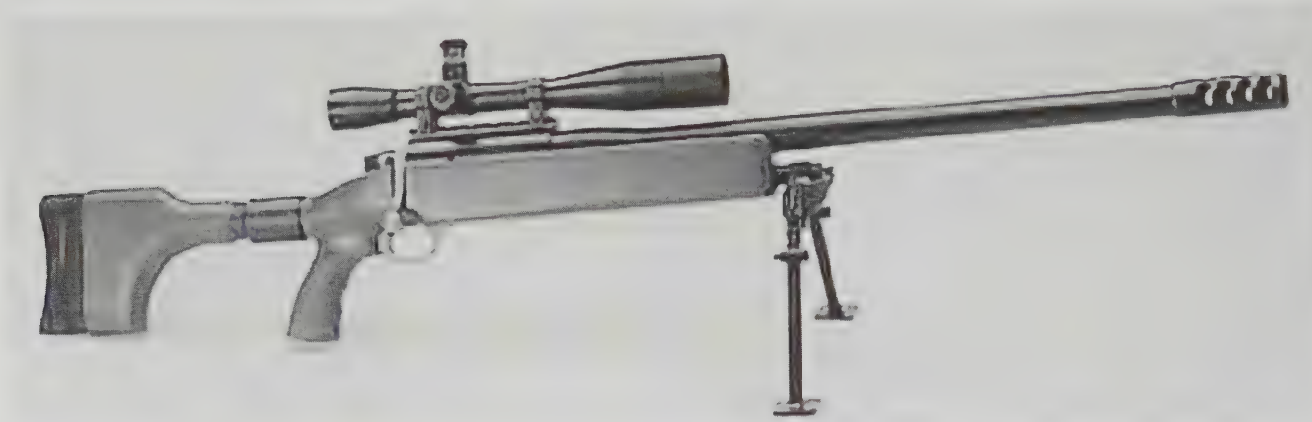
- **Data Tables.** This is probably the most important part of the puzzle. These are tables that give elevation settings and much more. These elevation settings all begin at a point where the barrel is assumed to be parallel with the scope base used. Take a look at the information on the sight base below and you see that this is not workable. This is where the process of PBZ comes in. All four elements are tied together into an ISS. With heavy-class rifles, data tables are as necessary as the ammunition itself is.

For an HTI team the communications process used between the observer and the shooter(s) is very specific and focused. The fact that there may be up to three shooters for the observer on a 4 man team can be vexing. For a normal sniper team, communications between the observer and sniper is a language of its own. Certain bits of information are always the same, but the method of transmission between the two is sometimes different. With an HTI team, data may be transmitted to additional shooters. Additionally, there may be a master observer that controls the efforts of a number of teams. This is much the same as an anti-sniper team doing protection operations. The master observer may direct priority fire onto targets that he deems necessary. The bottom line is the terms of communication are written in stone.

To someone that has never heard sniper team members communicate with each other, it sounds like a code. Many times, a lot of useless information is also passed. One of the classics is the observer telling the shooter where the bullet went when the shooter missed!!! Actually, that should read: “the shooter and



L&S mark IV bases one and two piece for Remington action.



Critical angle at base must be known for the PBZ process.

observer missed.” The observer should tell the shooter where to aim to correct the miss, period. This critical dialogue is used to speed up the time to the shot and pass lots of information in a short period of time. The most valuable and experienced member of a sniper team is the observer. A shooter is much easier to train than the observer. It is also not really necessary that the shooter be a trained sniper. If I had to do a critical shot, I would grab the nearest “good shot” and talk him into hitting the target. Doping the ENV and MET conditions is infinitely more difficult than pulling the trigger.

An observer must give directions and instructions to the shooter. He must give him all the information to put on the sight systems and also tell him where to aim on the target. These instructions for where to place the sights or what to place on the sights are transmitted in agreed-upon units of measure. The first part of this chapter focuses on these units of measure, what they mean, and how they are used.

The technical zero process and the theory of PBZ are two of the most critical elements of tying the shooter with the Integrated Shooting System. It is not sufficient to merely zero the rifle and sights so that the point of aim and the point of impact are the same at a determined range. As you will see in Chapter 6 , “Determining and Correcting for Meteorological and Environmental Conditions,” you must correct for ENV and MET conditions. This chapter will teach you how to put a SAC zero condition on your rifle and sight system.

You must also use a baseline round of ammunition for this initial zero. If Mark211, Mod-0 (Raufoss or Greentip) is available, it is suggested that you use this. Then the deviation from that round to the other rounds must be determined and recorded. Once the SAC zero is placed on the gun, you will then be able to apply the methods used in Chapter 3 so you and your weapon can be used in any ENV and MET condition encountered in the world.

UNITS OF MEASURE USED IN SNIPER/OBSERVER PROCEDURES

The intent here is that we understand the angular unit of measure used in sight corrections. On a range where two shooters have worked together and already have an agreed upon language, you will likely hear them saying things like, “Your first shot was two minutes to the right.” Here, the range and the size of the target are known. Even in a field environment, shooters will not discuss MOA or mil corrections until the size of the target and the range to the target are known. At times when these two items are unknown, they will commonly use “inches” to describe a distance on a target. Once they know the range and size of target, they easily slip into MOA or mils.

MOA and mils, both angular units of measure, are used for many things, including:

- Indexing elevation and windage settings on the sight system.
- Providing a common language for giving corrections to the shooter on initial and follow-up shots or in discussing targets of known dimension and range.
- Determining the corrections needed on the sights when zeroing the rifle.
- Calculating corrections for ENV and MET conditions.
- Describing the size of a shot group.

The Minute of Angle. An MOA is equivalent to 1/60th of one degree of arc. On all iron and optical sight systems, the MOA is used to place corrections on the elevation and windage knobs of the iron or optical sight. On scopes commonly used for hunting, the companies mark on the scope Each Click = 1/4 inch at 100 yards. It is important to note that, as in mathematics, you have to work in like units of measure. If you are working in yards, your unit of measure for MOA must be in inches. If the range is a metric range, you must work in metric MOA or centimeters. For example, you can say, “two MOA at 100 yards is 2 inches.” However, you cannot say, “2 MOA is 4 inches at 200 meters.” Inches are U.S. units of measure, and meters are in the metric unit of measure.

- One MOA = 1.0472” at 100 yds.
- One metric MOA = 2.9 cm at 100 meters.
- At 100 meters, a U.S. MOA would equal 1.14 inches.
- At 100 yards, a metric MOA would equal 2.65989 centimeters.

Obviously, the numbers above—stretched out several decimal places—would be hard to work with. As such, shooters round them off to a more abbreviated number to work with. We will agree that 1 MOA = 1 inch at 100 yards and 1 MOA = 3 cm at 100 meters. Using these acceptable rounded figures you lose only 1/2” at 1,000 yards and 2 cm at 1,000 meters.

When trying to determine the value of MOA at certain ranges there is a simple process. For example, what is the value of 2 MOA at 500 yards?

1. MOA @ 500 yards = First, drop the value of tens and ones off the range. Thus 500 becomes 5. Then multiply that 5 x the number of MOA. This tells you how many inches 2 MOA equals at the range desired.

$$2 \text{ MOA} \times 5 = 10 \text{ inches.}$$

What is the value of 3.5 MOA at 876 yards? In this case don’t drop the 76 value. Place a decimal point between the hundreds and tens value. The range then becomes 8.76. Then multiply the value of MOA against this new figure.

$$3.5 \times 8.76 = 30.76 \text{ inches.}$$

The Mil. The technically correct term is milliradian. Mils are simply another unit of measure used when breaking down a 360 degree circle. In sniping we use the artillery mil. There are 6,400 mils in 360-degree circle. Contrast this with the fact that there are 21,600 MOA in a circle. It is evident that the mil is a larger unit of measure than is the MOA. In field sniping there is only one real application for the mil.

Mils are used in range finding, however, we do not place a lot of emphasis on this method of ranging field targets. Mil-relation range finding requires that the enemy target be very still and show a good profile to get an accurate mil reading. In history, the enemy has tended to do neither of these. We will use mils for indexing corrections for holdoffs on initial and follow-up shots. To do this we must understand the value of the mil.

$$\begin{aligned} 1 \text{ mil} &= 3.375 \text{ MOA} \\ 1 \text{ mil @ 100 yards} &= 3.375 \text{ inches} \\ 1 \text{ mil @ 1,000 yards} &= 1 \text{ yard} \\ 1 \text{ mil @ 1,000 meters} &= 1 \text{ meter} \end{aligned}$$

In telescopic sights that have the “Mil Dot” reticle pattern, we have Mil Dots on the vertical and horizontal stadia lines. Many people misunderstand the term Mil Dot in that they think that this refers to the size of the dot. It does not. Where the term Mil Dot comes from is that the center-to-center spacing between the dots is 1 mil. The dots themselves are 3/4 MOA in diameter. More details on this later.

When a sniper team is operating, the observer uses a precise dialogue to give the shooter corrections. Remember above when we said his corrections are in an agreed upon unit of measure? When the sniper is told “Hold left 1 mil” he will place the reticle center crosshair 1 mil to the left of the target. The observer may say, “Lead 1 mil.” The result is the same. The sniper must understand explicitly what the observer is directing. Therefore, it is important for the observer to be clear and concise in his dialogue.

Common Units of Measure in Dialogue. When snipers are communicating in reference to visual corrections on the target, it is important for them to work in a standardized unit of measure. The most common mistake for the observer is to tell the shooter where the bullet went when a miss occurred. This is the wrong way. There is very little time after a missed first shot to get a second effective shot downrange. The observer must give the sniper the correction to hold left, right, up or down to generate a second round strike.

It must be decided whether to talk in MOA, mils, or inches. Any technique will work. During field shooting sniper teams engage targets of unknown distance. Initially the team agreed that holdoffs will be used as corrections (This method of correction involves holding the reticle on a different point on the target to compensate for the miss. It is faster than a mechanical correction, but not as accurate). If the observer gives a correction in MOA and the sniper is using a holdoff correction technique it causes to sniper to hesitate while he thinks of a solution. In field sniping a good method is to give a precise visual reference for the sniper to aim at. For example, after a first round miss, the observer would say “Hold on the left side of the hip.” With this instruction, the sniper does exactly that. He does not have to determine the value of any MOA or mil.

THEORY OF PARALLEL BORE ZERO

By definition, parallel bore zero (PBZ) is the act of tuning a shooter, a rifle, and sighting instrument to a firing table. When using PBZ technique, it is important that a SAC zero be established on the sighting instrument. The zero process can be done at any distance. It can be done on an unknown distance range. Using this method, you are able to do a zero in an operational environment (provided shooting bullets won’t compromise you). Initially, you determine the range and any slant range.

You must know the MET and ENV conditions and record them. You adjust the point of impact to the point of aim by moving the elevation and windage knobs until the rounds are impacting precisely where you

want them. Once you have adjusted the elevation and windage knobs to point of aim (POA) and point of impact (POI) coincidence, you will slip the scales or knobs to a MOA value for that range. Before you slip the scales you must correct the MET and ENV conditions. You must correct them from whatever they are when you shoot back to standard values.

Using this method, you are placing a zero on your gun that is based on SAC. This makes the sniper truly worldwide-deployable. He can fly anywhere, infiltrate and take a shot under any ENV and MET condition and have a very high percentage of success. To ignore this method is to ignore that there are ENV and MET effects. It is a common belief that rezeroing the rifle in the new MET and ENV conditions will automatically correct for this. Zeroing is done at reasonably short range (500M for heavy class rifles). All of the effects of MET and ENV do not effect the trajectory of the bullet until you are 500m+ out. However, slant range and ammunition temperature still will have a great effect on the zero, no matter what the range.

SETTING BASELINE ZERO FOR DIFFERENT TYPES OF AMMUNITION – M33 VS. M8 VS. MARK 211

Zeroing a heavy-class rifle is a bit different than zeroing other sniper weapons systems. With heavy-class rifles and nature of the mission, it is almost certain that the shooter will at times use a round other than the one that the rifle was zeroed with. He also may have a magazine with 2 different types of ammunition in it.

The .50-caliber SWS is the most common caliber of rifle in the military so we will use this caliber as our basis of discussion. There are 5 different type classifications that are readily available to the special operations sniper for use in the .50-caliber SWS. Chapter 2 contains more detailed information on each cartridge. The different rounds include:

- Mark 211, Mod-0. This round is also commonly referred to as Greentip. For the special operations shooter, it is the round of choice. Naval Special Warfare has adopted this cartridge as the standard for their shooters.
- M-33 Ball. This is the round most readily available to U.S. Army shooters. Unfortunately the Army Special Forces Groups have not adopted the Mark 211, Mod-0 round and are stuck with this round. It is usually issued linked and, believe it or not, the Army won't let you "legally" delink the ammunition. EOD is allowed to do it, but not the average guy. It has bad accuracy, but it was much better after 1994.
- M-8 Armor Piercing Incendiary. This round is available in small numbers within Army special operations. It is generally pretty accurate, but doesn't carry the destructive power of the Mark 211, Mod-0 round.
- M-20 Armor Piercing Incendiary Tracer. This is the tracer version of the M8 round. Because it gets lighter as it flies downrange, burning off its tracer compound, it has a flight trajectory that is somewhat different than the M-8 cartridge.
- M-903 Saboted Light Armor Piercing. This cartridge is a special armor penetrator that actually doesn't shoot very accurately out of the .50-caliber SWS. Part of the reason for this is that the barrels are twisted wrong for a projectile of this design and weight. Only weighing 350 grains and made out of tungsten steel, it is about half the weight of the other bullets in this class.
- M-17 Tracer. This is the tracer shot of the M-33 Ball round. As with the M-20 Armor Piercing Incendiary Tracer round, it gets lighter as it goes downrange and the heat off the tracer assists in cleaning up the vapor trail behind the bullet.

There is a set of precision zero cards attached to the end of this chapter. They also have callouts giving some details about the information asked for in the boxes.

BASE AMMO TYPE:	Mark 211, Mod-0
Example: Mark 211, Mod-0 and Lot #	

Follow the zeroing process as outlined in this chapter for the baseline round of ammunition. Using Mark 211, Mod-0 as the baseline round, here is the procedure for determining the deviations for each round from that baseline round:

1. Your elevation and windage knobs should be slipped to the range value that you have zeroed the baseline round at. Windage should be at zero. MET and ENV conditions should be calculated out so that there is a SAC zero on the gun.
2. Select your next type of ammunition and enter it in the space provided on the zero card. M-8 is used in the case below.

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API	+2.00 Elev.	Left 2.00 MOA	Lot# DM 10

3. Shoot in 5-round groups. It is suggested that you shoot at least 15 rounds to establish the difference in the zero. Be precise and measure the difference between the "X" on your target and where the center of the groups form. The more rounds that are fired, the more accurate your recorded deviation will be. Enter the deviation, up or down, and left or right on the card. The data entered should be the correction needed on the scope, not where the rounds went on the target. This is very important!
4. Select and repeat for any other cartridges that you may have available.

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API	+2/00 MOA	Left 2.00 MOA	Lot DM 101
M-20 APIT	-1.75 MOA	Left 2.25 MOA	LC-812-90
M-33 Ball	-2.25 MOA	Right 1.00 MOA	LC-435-01
M-903 SLAP	-8.00 MOA	Right 3.00 MOA	LC-888-54

If sniping were a religion, then zeroing a rifle would be its preacher. Follow the rules, take the time, do the math, and you'll be rewarded for your efforts. Hopefully this will clear up some of the haze that occurs when bullets miss.

THE PARALLEL BORE ZERO PROCESS

The PBZ process begins with having the elevation (Primary Function) tables for the weapon and round of ammunition that you are zeroing for. In other publications, a field expedient zero is mentioned where you fire at an object at which you have determined the range, then slip the scales to the value of that range. In using PBZ, you can do the same thing but with better results, as you will calculate out nonstandard ENV and MET conditions.

SIGHT ADJUSTMENT AND ZERO OF THE HEAVY RIFLE

1. Determine the range at which you are going to set parallel bore. This does not necessarily have to be on a known distance range. You do have to know to the nearest yard or meter the range. Example: 554 meters.
2. Determine and record the ENV and MET conditions as they exist. (Slant Angle = 18 degrees, 24.65 In. Hg, 88 degrees F, ammo temp = 90 degrees F.)
3. Establish the target.
4. Select a round of ammunition to use for the baseline zero round.
5. Determine the point of impact (POI) desired on the target. Be as precise as possible.
6. Fire 5-round groups and make adjustments off the groups, not individual shots, so that point of aim and POI are in coincidence. (Bullets strike where you are aiming them.) Do not slip any scales yet.
7. Refer to the elevation table, and obtain the MOA value for the range at which you are zeroing. Do not slip any scales yet.
8. Using methods taught in Chapter 6, "Determining and Correcting for Environmental and Meteorological Conditions," correct this elevation MOA setting to standard conditions from the MET and ENV conditions in which you are zeroing. Basically this is done by adding the MOA corrections to the superelevation MOA instead of subtracting them (if this would have been correcting for a shot). Once this is calculated, place this correction on the sight. This sets the true SAC zero setting for the sight. (Superelevation refers to the total number of MOA from the absolute bottom setting on the scope. It refers to a cumulative number.)
9. Loosen the elevation knob (scope) or the major scale plate (Palma) and slip the knobs or scale to indicate a value for the MOA that you determined in step 7 above. Details on each sight system are covered later in the lesson.
10. Refer to the elevation tables. Determine the superelevation MOA value for the range you are shooting at. If you are using a 1/4-MOA sight you loosen and slip the elevation knob to the MOA value for the range you are zeroing at. If you are using a scope with a BDC, you will slip the BDC to the value on the BDC for that range.

EXAMPLE: You are zeroing at 500 meters. The MET and ENV conditions are standard. Referring to the Mark 211, Mod-0 table, you slip a value of 13.75 MOA on an M1A scope or the 1/4 MOA iron sight. If this were a scope with a BDC, you would slip the ring to the value of 5.

11. If you are using an M1A or other 1/4 scope or sight, you turn the elevation knob DOWN 9.50 MOA. Read the scale and you will note that the scale or knob is at 0. You have just set a parallel bore zero on your sight. At this point the rifle and ammunition are tuned to the firing table and under standard atmospheric conditions.
12. Details of each sight system are covered below in their respective section on the PBZ process.

BALLISTIC DATA MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL. AMMUNITION							
RANGE	SUPER ELEV.-MOA	SUPER ELEV.-MILS	SUPER-ELEV. PER 100 METERS	TEMPERATURE CORRECTION FACTORS	BAROMETRIC CORRECTION FACTORS	ALTITUDE CORRECTION FACTORS	REMAINING VELOCITY
500M	13.75	4.10	3.25	1.00550	1.00000	1.00000	2067 FPS

ZERO PROCEDURES FOR THE LEUPOLD & STEVENS MARK IV, M3A TELESCOPIC SIGHT

While scopes using BDCs are not the norm on heavy-class rifles, they have been used. This part of the chapter will teach you how to place a SAC zero on the Mark IV, M3A or other scopes with BDCs. The BDC

used on the M3A scope is sometimes referred to as a ballistic cam. This is incorrect terminology. The term ballistic cam is a leftover from the days of the ART series of rifle scopes and refers to a device that actually moves a rifle scope body to compensate for ranges that correspond to targets. There is a ring around the scope body that rides a spring-loaded button on the sight base. As the ring is turned to the corresponding range, the cam lifts the scope and thereby compensates for the bullet drop. The target scopes built by Unertl, Lyman, and Redfield have exterior adjustment knobs that move the scope body up and down. These are not ballistic cams.

The new night sight, the long-range version of the AN/PVS-10 does have a BDC. As of this writing, it is not known what round of ammunition this BDC is tuned for. Again because there are a number of heavy rifles out there with BDC-type rifle scopes on them, we will cover in detail the BDC system.

As you turn the BDC knob you will note that there are tactile clicks between the numbers. Each of these clicks represents 1 MOA. It is important for any shooter to understand that each of these numbers represent specific MOA values for these ranges. Not all scopes with BDCs work this way. The Kahles or Swarovski scopes have BDC rings, however, there is no tactile click for MOA between numbers. There are only clicks at the number value themselves and in some cases at the halfway point between range values, 350 meters, for example.

Very little attention is paid to the value of these numbers on the BDC knob of the M3A scope. In the vast majority of cases, the shooter does not know the MOA value of the range number on that ring. Many would say that they do not need to know. Wrong in both cases. First, fundamentally, a sniper must know every detail about his weapon and scope system. That rule goes back as long as there have been snipers. Also, to ignore what these values are is to ignore the effects of the ENV and MET conditions as they exist. Note in the above example that the MOA value for a 4 setting on the knob relates to 13.00 MOA. This means that the barrel is elevated 13.00 MOA from parallel to the line of sight from the eye to the target. Remember that bullets do not “rise” on their own. They only rise because a barrel is elevated a specific degree of angle that compensates for bullet drop.

There is no PBZ for the M3A, per se. It has a BDC that you index to the range at which you are firing. You do however correct the zero to standard atmospheric conditions. Because this ring is calibrated in meters, it is preferable that you zero the scope on a metric range. Below is the zero process for placing a SAC zero on the gun.

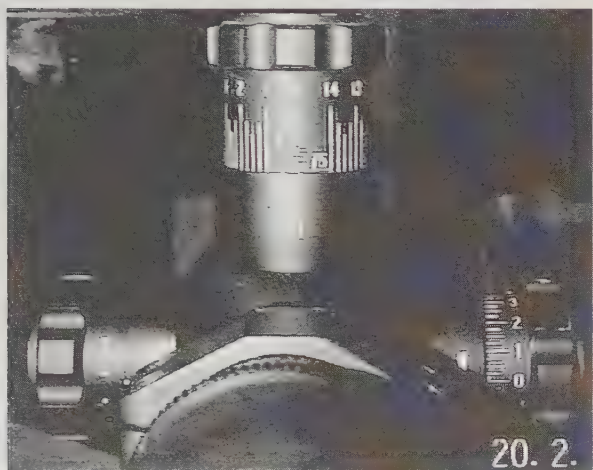
1. Determine the range at which you are going to set the SAC zero. This does not necessarily have to be on a KD range. You do have to know to the nearest meter what the range is. It is suggested that the zero is executed at 300 meters. However, the longer the range the more precise the zero (out to 600 meters). Keep in mind the winds.
2. Determine and record the ENV and MET conditions as they exist.
3. Establish the target. It is suggested that the NRA, Rifle, Target “A” is used.
4. Select the type of ammunition to use for the baseline zero.
5. Determine the point of impact desired on the target. Usually the “X” ring.
6. Fire 5-round groups and make adjustments off of the groups, not individual shots, so that point of aim and point of impact are at the same point (the bullets strike where you are aiming them). Do not slip the rings yet.
7. Loosen the elevation knob tension screws (2) and rotate the knob so that the numerical designation is in alignment with the index mark on the scope turret. Retighten the screws.
8. Write down the MOA value for the range at which you are zeroing. Using methods taught in Chapter 6, correct this elevation MOA setting to standard conditions from the MET and ENV conditions in which you are zeroing. Subtract the two MOA values. Determine whether you need to turn the knob up or down. Basically this is done by adding the MOA corrections to the superelevation MOA instead of subtracting them (if this would have been correcting for a shot) Once this is calculated, place this correction on the sight. This sets the true SAC zero for the sight.
9. Again, loosen the locking screws and rotate the knob once more to the range at which you zeroed (usually 300 meters).

10. Confirm the point of aim and point of impact are coincident by firing a group of five rounds.
11. You now have a SAC zero on the telescopic sight. From this point on, if you dial a range on the scope, that setting indicates a trajectory that corresponds to SAC only. Remember to determine the corrections for ENV and MET and index them if you have time and the difference is significant.
12. Select your next type of ammunition and enter it in the space provided on the zero card.
13. Shoot at least 5-round groups. Enter the deviation, up or down and left or right on the card. The data entered should be the correction needed to compensate for the different round, not where the bullet struck on the target in relation to X!

INTRODUCTION TO THE LEUPOLD & STEVENS MARK IV, M1A TELESCOPIC SIGHT

The M1A telescopic sight is very different than the M3A scope. In terms of indexing elevation settings and making corrections, it is quite similar to the Redfield Palma Iron Sights. This sight is found on virtually any SWS that is built in the free world, including the .308 class weapons. Current applications in the SOF community are on the M700 .300 Winchester Magnum (M-91) built by NSWC, Crane selected .50-caliber

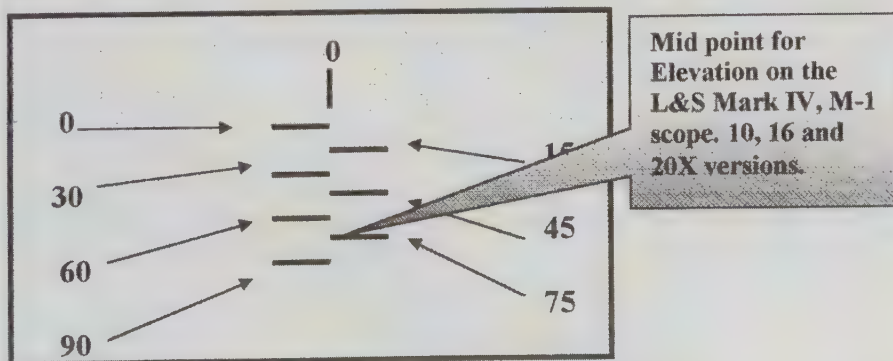
SWS, M-91 in 7.62mm built for U.S. Navy SEAL teams as built by NSWC, Crane. There are two different versions of the M1A Scope. Mechanically they are all the same except the power factors of the scopes and the available elevation range in each.



1. M1A 10 Power. The 10 X scope has only 90 MOA of elevation available for use in zeroing and elevation settings. It has 45 MOA of windage available for zeroing and corrections.
2. M1A 16 and 20 Power. The 16X and 20X have 150 MOA of elevation available for zeroing and elevation settings. On long-range rifles the 16X and 20X are preferred over the 10X because of the range of elevation available.

The elevation knob on the M1A scope is referenced in MOA. It is not to be considered a BDC or a ballistic cam. With this system you have to have a table of elevation settings. These elevation settings are indexed on the elevation knob. This creates some problems with standardization between shooters, weapons, and units as to where the baseline lies in zeroing the rifle and its optics.

One common practice in using this optical sight is to choose a range at which to zero the rifle. The shooters place windage and elevation corrections on the sight until they have point of aim and point of impact coincidence. They then move the rifle back every 100 meters or yards and write down the elevations needed to hit the



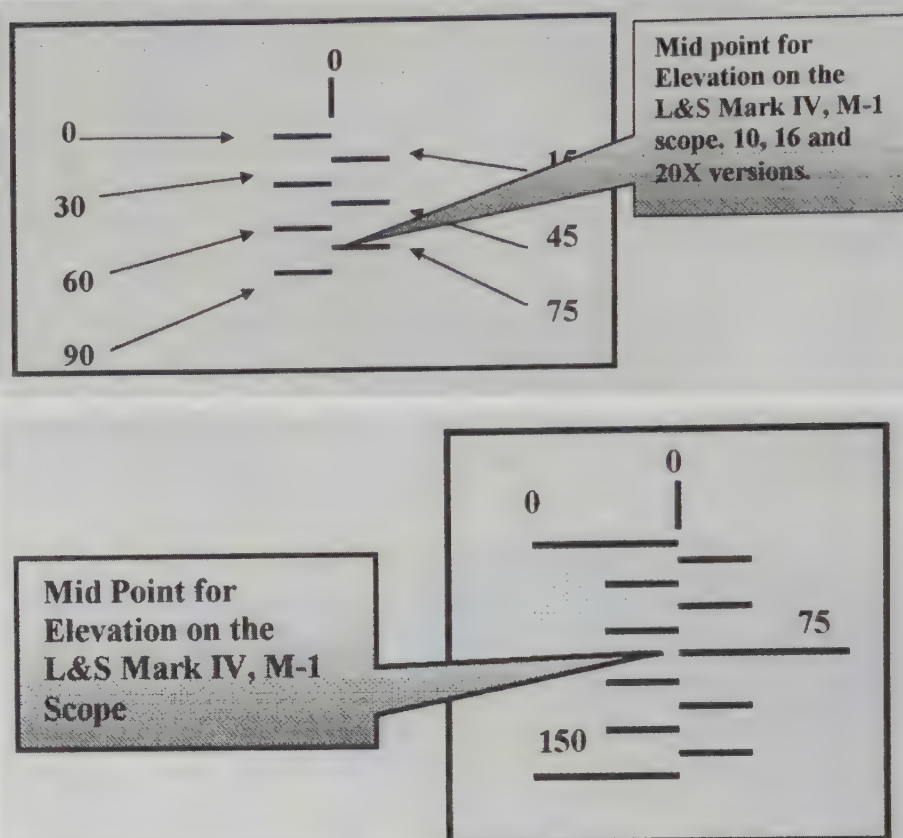
Point of Aim at each desired range. This is fine if the MET and ENV conditions never change. For this reason we place the SAC PBZ on the rifle.

The elevation knob on the M1A has a series of hash marks on it that go around the entire knob. Each of the longer hash marks represents 1 MOA. Note that these long hash marks correspond with a number. On the knob you will see numbers from 1 through 15. These numbers represent MOA values. Note that between the long hash marks there are shorter hash marks. There are three of these between each long hash mark. These short marks represent 1/4-MOA values. It is important to note that there are two versions of the elevation knob in use. Below are the explanations of each.

Up until this point all of the visual and technical explanations were the same for both types of elevation knobs. Turn the elevation knob so that the value of 0 faces you and turn the knob counterclockwise all of the way up until the knob hits its limit of travel. Once it hits the limit of travel, turn the knob clockwise until the 0 is lined up with the white reference mark on the turret ring.

On version 1 you will note that there are only short horizontal hash marks that are offset from each other directly below the value 0 on the knob. Each full rotation of the knob will elevate the sight 15 MOA. Note that there are numbers from 0 to 15 on the knob. In this version there are no numerical values indicated on the vertical scale. Below is the value of each horizontal hash mark. When you can see all 7 hash marks, there are 90 minutes of elevation on the knob.

On version 2 you will have a more detailed scale value shown on the elevation knob. Remember that the 16X and 20X scope have 150 MOA available for elevation settings. Generally, on the 150 MOA scopes this is the elevation knob that is used.



INDEXING ELEVATION SETTINGS ON THE M1A

Turn the elevation knobs clockwise until the knob is set at a value of 0. To do this, turn the knob clockwise all the way until the knob hits the stops. Then turn the knob counterclockwise until the 0 is indexed above the white vertical index line.

- a. For elevation settings under 15 MOA, the process is simple. You merely turn the knob counterclockwise

the required MOA until that value is indicated on the elevation knob. For example, to index 7 MOA, turn the knob until 7 is aligned with the vertical white index line.

- b. Elevation settings more than 15 MOA require a little careful work. Remember that each rotation of the knob will elevate the sight 15 MOA. The elevation knob will be at a position of parallel bore, with the "0" values indexed. Use the following example: Index a value of 22 MOA. Grasp the knob and turn it one full rotation counterclockwise. You will note that the first horizontal line on the right side of the scale is showing. There are now 15 MOA indexed on the scope. Continue to rotate the knob counting past the individual numbers and adding to 15 as you go: 15, 16, 17, 18, 19, 20, 21 and stopping when you reach 22. Note the setting number that is aligned with the vertical white line. This is the value of 7. A total of 22 MOA is now indexed on the gun.
- c. It is important to reset the sights to parallel bore every time you case the gun, move to another firing position, or move to another KD firing line. This is done to avoid confusing the shooter as to the value of the sight setting when he arrives at a new firing position. This may be under great stress and the sniper doesn't need the additional problems. It takes practice and attention to detail to not mess up this process.

Below are the technical specifications of the M1A rifle scope.

- 10, 16, or 20 power (fixed).
- 40mm objective lens
- 1/4 MOA value for each click of elevation.
- 1/4 MOA for each click of windage.
- 90 minutes of elevation available on 10 power scopes.
- 150 minutes of elevation available on 16 and 20 power scopes.
- 30mm main tube diameter.
- Adjustable for parallax
- Ability to index elevation settings for virtually any external ballistics environment that may be encountered. The scope has no BDC or ballistic cam.

There are two reticle patterns used on these scopes. They are fundamentally the same as the reticle on the M3A scope. The only difference is the diameter of the dots on the reticle. Some scopes have dots that are 1/4 MOA in diameter. The other reticle pattern has dots that are 3/4 MOA in diameter.

Bases to Use on Rifles with the M1A Scope

In SOF there are a number of rifles that have the M1A scope on it. Many years ago when the .50-caliber bolt-action rifles were built, manufacturers understood that the mounting base for the scope had to have a 1.5-degree of tilt in the base. The reason is that the scopes have 90 and 150 MOA available travel. The problem is that the centerline of this available travel is at 75 MOA. On bases that have no tilt in them (M-91, .300 Win. Mag. from JOS) and other parallel bases, the shooter will have to bring his sight up 75 MOA to just get the gun on paper at 100 meters. Subtract this figure from the available range of elevation and you see the problem. You quickly run out of elevation on the 90-minute scope and with the 150 minute scope there is plenty. The major problem is that it is very easy to get lost on the scope knob when you cannot function the scope from dead 0.

ZERO PROCEDURES FOR THE LEUPOLD & STEVENS MARK IV, M1A ULTRA TELESCOPIC SIGHT (OR OTHER 1/4 MOA AND 1/2 MOA SIGHTS).

The PBZ process is very important for the Leupold and Stevens Mark IV, M1A telescopic sight. It establishes a standard bottom line setting that is calibrated to standard atmospheric conditions. Current instructed technique suggests that you zero an iron sight at perhaps 200 yards. Then you slip the scale to 0 and determine the come-ups for each range every 100 yards or meters out to a range of 900 meters. This does not take into account ENV and MET conditions and the results are disastrous. Here is the process:

1. Determine the range at which you are going to set parallel bore. This does not necessarily have to be on a KD range. You do have to know the range to the nearest yard or meter the range. It is suggested that the zero is executed at 300 yards, however, the longer the range the more precise the zero (out to 600 yards). Keep in mind the winds.
2. Determine and record the ENV and MET conditions as they exist.
3. Select a round of ammunition to use for your baseline zero.
4. Establish the target. It is suggested that the NRA, Rifle, Target "A" is used.
5. Determine the point of impact desired on the target. Usually the "X" ring.
6. Fire 5-round groups and make adjustments off the groups, not individual shots, so that point of aim and point of impact are at the same point (the bullets strike where you are aiming them). Do not slip the knob yet.
7. Refer to the elevation table, and obtain the MOA value for the range at which you are zeroing. Do not slip the knob yet.
8. Using methods taught in Chapter 6, correct this elevation MOA setting to standard conditions from the MET and ENV conditions in which you are zeroing. This determines the true SAC zero setting for the sight. Do not slip the knob yet.
9. Loosen the screw holding the elevation knob and slip the knob around to the value in MOA for the elevation setting you determined in step 7. Remember that if the setting is less than 15 MOA you just spin the knob to the MOA value. If it is larger than 15 MOA you must subtract 15 MOA from the elevation setting and spin the knob to this value. You have now placed a SAC zero on the elevation knob.
10. Turn the elevation knob down (clockwise) the number of MOA determined after correcting the elevation setting to SAC. This is total minutes. If you zeroed the rifle at a range with 38 MOA (the value of 8 would be showing on the knob) elevation after corrections for ENV and MET, you turn the sight down that 38 MOA (two full revolutions + 8 MOA). This places the scope at parallel bore.
11. Zero the windage knob.
12. Select the next type of ammunition and enter it in the space provided on the zero card.
13. Shoot at least 5-round groups. Enter the deviation, up or down and left or right on the card. The data entered should be the correction needed to compensate for the different round, not where the bullet struck on the target in relation to X!
14. From this point on, you will determine the range to the target and extract the sight setting from the ballistic table. Correct that setting for MET and ENV conditions. Place the setting on the sight and shoot.

INTRODUCTION TO THE SWAROVSKI 10 X 42 TELESCOPIC SIGHT

The special section for this sight is intended for the U.S. Army shooters and any others that are using the Swarovski sight on the Barrett .50-caliber rifles. It is currently used on most of the Barrett M82-A1. Many of the M82A-A1 rifles have Leupold & Stevens M1A scopes on them. The Swarovski scope has the patented Barrett reticle pattern in it. The reticle pattern is good in theory but not so good for precision shooting. Details on the

reticle are covered in following paragraphs. While the scope is of high quality and is very durable it is the absolutely wrong optical sight for the .50-caliber rifle. Chapter 6 will clarify why this sight is the wrong choice.

The Barrett Reticle Pattern

The major claim of the Barrett reticle pattern is its ability to quickly place a range value reticle on the target that the range has been identified and pulling the trigger. There are major flaws in this approach. First, the reticle has elevation stadia lines that correspond to the ranges indicated. In SOF, there are five different types of ammunition to use. All of these have different flight characteristics. At ranges past 1,000 meters, these trajectories are radically different. The Barrett reticle is based on M33 Ball ammunition. This is the lowest quality ammunition to use.

The technical specifications on the Swarovski scope are as follows:

- 30mm aluminum tube
- 10 X fixed power
- 42mm objective lens diameter
- 1/5 MOA elevation and windage adjustments

As with the M3A there is no PBZ for the Swarovski scope. It has a reticle that is graduated in hundreds of meters from 500 to 1,800 meters. It is recommended that shooters carefully reconsider before using the printed data that is in the operator's manual on the M82A1. The data contains rough generalizations that have major accuracy problems. Remember that the reticle pattern is calculated based on M33 Ball ammunition. We use different types.

Also remember that when firing other types you will experience differences in impacts at longer ranges. Fifty-caliber competition shooters all have handmade loads that have trajectories that are different from the military loads. Always remind yourself that the reticle is intended as a rough tool only. However, when faced with no other option you must know how to extract the maximum performance out of this optical instrument.

ZERO PROCEDURES FOR THE SWAROVSKI AND LEUPOLD & STEVENS MARK IV, M3 SCOPES USING THE BARRETT RETICLE PATTERN

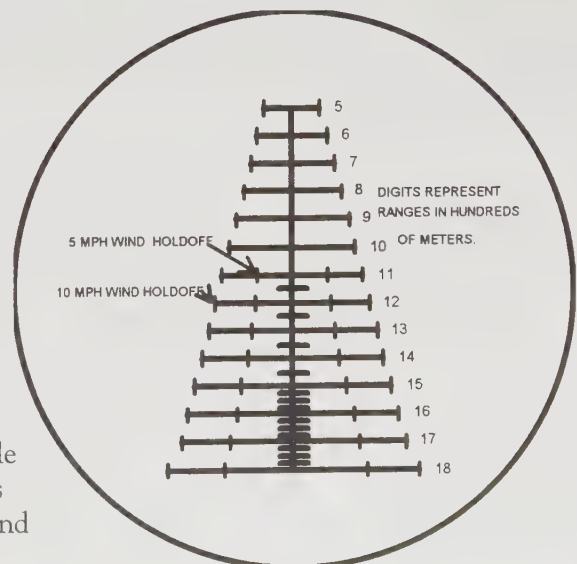
Major Points of the Barrett Reticle Pattern

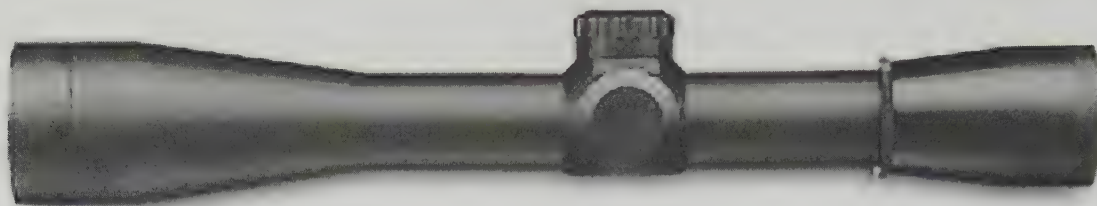
Pros:

- Tuned for M-33 Ball ammunition
- Good item for fast targeting when rifle is used in conventional infantry support roles.

Cons:

- At extreme ranges (past 1,000 meters) the difference in flight trajectories between the different rounds of ammunition is unacceptable for first-round hit expectation.
 - Wind correction tick marks are in error at extreme ranges (past 1,200 meters).
1. Because of the design of this reticle you must zero the rifle and scope at a range of 500 meters. Because of this winds may be a major factor. Zero for elevation at 500 meters and then move closer for a no-wind zero.





2. Determine and record the ENV and MET conditions as they exist.
3. Select a round of ammunition to use for the baseline zero.
4. Establish the target. It is suggested that the NRA, Rifle, Target "B" is used.
5. Determine the point of impact desired on the target. Usually the "X" ring.
6. Remember to use the reticle that corresponds to the range at which you are zeroing. You do not have to zero at 500 meters. However, you cannot zero at ranges less than 500 meters unless you calculate the desired point of impact (high). If zeroing at ranges greater than 500 meters use the corresponding reticle crosshair value for that range.
7. Fire 5-round groups and make adjustments off the groups, not individual shots, so that POA and POI are at the same point. Remember that the clicks on the elevation and windage knobs are in 1/5 MOA. Adjust the windage as necessary to get the bullets in the "X" ring.
8. Write down the MOA value for the range at which you are zeroing. Correct this MOA setting for air temperature, barometric pressure, ammunition temperature and slant range if any. Subtract the two MOA values. Determine whether you need to turn the knob up or down. Divide the MOA difference by 5 to determine the number of clicks to take the knob up or down. Index the change.
9. You now have a SAC zero on the telescopic sight. From this point on, if you shoot at a target using a reticle crosshair that corresponds to the range, that setting indicates a trajectory that corresponds to SAC only.
10. If necessary, move closer and obtain a no wind zero by firing at the "X" ring, accepting high strikes because you are using the 500 meter reticle. Dial the windage knob so that the groups fall into a straight vertical line from the center of the target. This places a no-wind zero on the scope.

When you change the elevation and windage settings on a rifle where the sights are mechanically centered and the rifle is mechanically sound you are dialing corrections into the sights that are reflections of the shooter's poor input into the sight and rifle system.

Another important point to remember is that in a course a zero will change based on the previous training level of the shooter. In a sniper course this usually takes place once or twice during NMC training. It usually occurs once during snaps and movers and it will occur once or maybe twice during field shooting. Remember this and expect it. Be ready to explain this to a student who questions why his zero changed. Rarely is it the mechanical system, but it may be.

ZEROING THE HEAVY CLASS RIFLE WITH NIGHT VISION SYSTEMS

Zeroing heavy class rifles with night vision devices (NVD) is difficult to do for many reasons. The overpressure usually destroys some of these systems in short order. The older model SIMRAD KN-200 series is not recommended for use on heavy rifles. The AN/PVS-4 series definitely would never stand up to the

punishing overpressure from these guns. The .50-caliber SWS that comes from the Joint Operational Stocks warehouse has specific instructions. Use only the SIMRAD KN-250 on the Barrett rifle. Hopefully, the 12X version of the AN/PVS-10 will be available so that using dedicated or piggyback systems won't have to be used. But until that time, we are stuck with those other systems.

The night vision sights that are used on the light- and medium-class guns are pretty much the same ones used on heavy guns, save for what's mentioned above. They fall into the same classes of systems. These system types are:

Dedicated Night Vision Sight

An example of this sight is the AN/PVS-4. These sights cannot handle the energy, however, and are soon rendered useless. A larger version of this sight, the AN/TVS-5 is intended for heavy crew served weapons and does quite well. These dedicated systems are sights that totally replace the day scope. The day scope is removed and the night sight is put in its place. The major problem with this system is usually the sight / base interface. Problems have included weak cases on the NVD, single point interfaces between the NVD and the rifle base, and mistakes in the machining process that do not result in good sight on/off repeatability of the zero.

Piggyback Systems

These are the same systems used on light- and medium-class weapons. Piggyback systems are night vision sights that attach to the day scope already in place on the rifle. Different models have been made that attach in all manners. Some attach to a rail on top of the day scope (SIMRAD). Some screw into the front of the day scope. Others attach to the back of the ocular lens portion of the day scope. The most famous of these systems is the Kigre SIMRAD series. This system attaches to the top of the day scope and the amplified image is reflected over a set of mirrors into the front of the day scope. Another version of this scope is called the NADS-850. A company called NVEC made a claim in its literature that the sight "maintained accurate boresight alignment even after more than 1,000 rounds of 7.62mm and .300 rounds of .300 Winchester Magnum live fire." Additional testing required 100 cycles of attachment to and removal from a Leupold & Stevens 10X day scope mounted on the M-24 SWS.

Combination Day/Night Systems

There is only one of these systems being made in the United States. It is the Litton AN/PVS-10. This system is a totally integrated day and night scope. There is no additional sight system to carry. It tensions the base in two points, the same as the day sight that it replaces. The sight maintains the same 2 degree field of view, reticle pattern, elevation and windage adjustments and rail interface as the Leupold & Stevens M3A scope. The new long-range version is 12X and has a BDC for the .50-caliber round. It has not been determined which round that BDC will be tuned for.

Stacked Dedicated Systems

Night vision sights are becoming more and more common in the public. As a result of this, many companies are coming up with some very interesting ideas and methods. The UNITEC series of night vision sights are very innovative, but not too passive, meaning they can be detected by other systems. They have a passive vision system stacked with an infrared illuminator for very low light situations. Not desirable, but may be necessary for certain situations. Another tool in the tool box.

THE NIGHT VISION ZERO PROCESS

Zeroing NVD sight systems is a little more difficult than the process is with day optics. There are many types in use. AN/PVS-4s work OK, but they are difficult to KEEP zeroed. They have no trajectory

compensation systems, so using a reverse image zero works the best for them. The methods of zero as well as any special “quirks” for each system type will be covered independently.

Most of the trouble that I have seen in zeroing night vision sights is that operators don’t take the same careful steps that they would take with day sights. Time after time I have seen operators changing their position on the ground or doing other things with their rifle or body that they wouldn’t dream of doing in the daytime. Part of this is because as much as people believe special operations can snipe at night. The reality is that capability is severely limited. As of this writing, Army Special Forces Groups still do NOT have the ability to shoot and kill targets at night.

The instructor pool with a base of knowledge for teaching this art is also extremely limited. After all, if there were no night vision systems for Special Forces snipers to use, how would they learn the art when they became instructors? Much of this fault, if not all of it, lies in one word: COMMAND. So when it comes time to teach sniper students how to zero and shoot at night, much of it is guesswork, or trial and error. Many errors are made and much frustration is felt. Many, many times you would hear the words “this piece of crap won’t shoot” and instantly the blame is shifted onto the piece of equipment, when the true fault lies in the training shortfall. Granted, at times, the equipment is trash, but not in the majority of the cases.

General Rules for Zeroing at Night

There are some major rules to follow that apply to all the sight systems. Follow these principles and if the equipment is working right, shooting at night is successful and quite fun:

1. Make a thorough systems check of the rifle, the scope base, and the night vision sight before beginning the zero process. Ensure all bolts are correctly torqued and that machined mating surfaces are free of garbage nicks and burrs. Shake the NVD around a little and see if there aren’t things rattling around in there. If there are, that’s very bad.
2. Don’t do anything different at night in preparation for shooting. There are a number of things that shooters do in the daytime in preparation that they do not do at night. I’ve seen snipers carefully prep and clean their rifles before a day shoot. At night before it gets dark, for some reason they don’t do the same careful preparation of the system. This includes cleaning the gun, laying out your gear, setting up ammunition, preparing your record-keeping materials (Zero Cards, plastic trash bag to keep your paper stuff in if it’s raining, tools for adjusting sights, reference materials, radios and batteries, etc.).
3. Record all of the ENV and MET conditions and determine the MOA difference from SAC. Don’t rule anything out until you have mathematically accounted for it. Even if it is only a 1 MOA difference, at the extreme range of your shooting envelope that 1 MOA can be a stone miss for a headshot. DO NOT RULE IT OUT. Crunch the numbers for MET and ENV as close to shooting time as possible. Atmospheric conditions can change faster at night than in the daytime. This is especially true because honestly, most guys want to get done and get home, so the conditions are rapidly changing in the hours when night “fun” is best had. Relax and wait for conditions to stabilize.
4. Determine the environment you are going to operate in, if possible. For most systems when shooting at night, it is recommended that you zero your rifle with night sights at a certain range and don’t mess with the adjustments at all. This is not necessarily true with sights like the AN/PVS-10 Day/Night sight. Even with sights with BDCs or sights like the SIMRAD, it is faster to use a PBZ or a reverse image zero. At night, the shooter is more likely to see a target first. In any case, the dialogue between a shooter and the observer is much more difficult at night. Many times the sniper will be his own observer at night. If your mission analysis shows that terrain will allow only shots under 500 meters, use a 500 meter reverse image zero. See Chapter 9, “Application of Fire,” for more information. Bottom line, if you are going to shoot 500 meters, then zero at 500 meters.
5. Use only one type of ammunition for shooting at night and zero with that ammunition. Just as with the

daytime, select your most commonly available or specified round. Don't change it for nighttime. You are more likely to be familiar with that round. Night zeroing and shooting is rare. Enter as few distracters as possible

6. When zeroing with a totally new sight or one that you have not used before, don't waste your time by starting to zero at long range. As the sun or light is going down, use the daylight cover and get a rough zero at 100 meters. This will tell you if you are having any mechanical problems before it gets too dark to mess with it. It is also easier to move around on the range. The sniper can quickly walk to the target and judge for himself how things are going. An important point: dedicated NVDs such as the AN/PVS-4 and AN/TVS-5 sit very high above the bore centerline. Shooting point of impact to point of aim at 100 meters will give you a decent start on a very good zero. Each system has an operator's manual that gives the offset data for short range zeros. Bottom line though, zero the rifle at the range you intend to operate or use a reverse image zero.
7. Carefully prepare your shooting position. If you are going to operate off a bipod, zero that way. A sand-filled sock under the toe of the rifle isn't a good idea for tactical field shooting, but for zeroing a night sight, it helps. Many shooters change their shooting position for some reason. They wiggle around and such. Don't do that. The only thing that I have seen that works better at night position is shooting with the opposite eye. On the AN/PVS-4, right-handed shooters will notice that their neck and shoulder are much less stressed when looking through the left eye. This is because the PVS-4 extends much farther back toward the shooter than does the day scope.
8. Be precise about your range to target. If you are on a known distance (KD) range, be sure that it is exactly the distance you assume it to be. At Fort Bragg, Range 66D, the 300 "yard" line is 300 meters, exactly. At Fort Lewis the 1,000 yard line on Range 22 is 1,036 yards. There is an allowance for error on many ranges. Not really anymore, but many ranges on U.S. installations were made 50-60 years ago. Precision was not a hot item at many installations, speed was. If you are trying to put a 500-meter zero on your rifle and the distance is 550 yards, problems will occur.
9. Have good communications with the target man on YOUR target. Being able to talk to your target man (who is usually the observer, since he can't do much on a KD range) is essential for decent speed and accuracy in making corrections. He can measure the shots in the group (5-round groups) and radio the shooter the exact correction to place on the sight's elevation and windage knobs. Too many times, spotters are simply stuck in the target and the shooter takes a guess at the correction. Much ammunition and time is wasted this way. Talk to the target puller and be accurate.
10. Record all data precisely and religiously. It may be a pain in the butt, but fill in the information in the zero cards. Some time down the road (maybe a long time, but it will come) you will wish that you did just that. Any little nuance may make a difference between life and death. Record everything!

These rules apply to almost any range-shooting situation anyway. Just be a bit more serious about following them on a night zero shoot. The process can be done somewhat quickly provided you have your stuff together. If things are not well prepared, the shoot will turn into hell and your zero will be worthless. You have to have confidence that your night zero can kill a target under the conditions you expect to operate in. If you don't feel 110 percent confident, do it again.

ZEROING DEDICATED NIGHT VISION SIGHTS. (AN/PVS-4, AN/PVS-2, LITTON M-995, LITTON AQUILA, ETC) GENERATION II, II+ AND III

These systems are sights that totally replace the day optical sight. This means that a very critical event will occur. That is removing and replacing one sight with another sight. To the sniper, the biggest fear here is

the repeat of his zero. Before we can talk about zeroing NVD sights, we have to understand what it takes to make sure that the sight systems will repeat their zero. This is done by inspecting the gun as well as the day and night sight. The zero procedure is as follows:

1. Determine the range at which you are going to set your night vision zero. This should be on a KD range. You do have to know to the nearest yard or meter the range. It is suggested that the zero is executed at 500 meters for a reverse image zero. Determine and record the ENV and MET conditions as they exist.
2. Select and record the base ammunition type, example: Mark 211, Mod-0.
3. Establish the target. It is suggested that the NRA, Rifle, Target "A" is used.
4. Determine the point of impact desired on the target. Usually the "X" ring.
5. Load and shoot 5-round groups and adjust your point of impact off of groups, not individual shots. Use common sense. If the first two shots are 2 feet out of center make a gross adjustment and go for a group of 5. For a reverse image zero, adjust point of impact to point of aim at 500 meters. Do not slip any knobs, if you have them to slip, yet.
6. If your NVD sight, such as the Litton M-995 Night Ranger, has a BDC refer to the elevation table, and obtain the MOA value for the range at which you are zeroing. Slip the knob to the range at which you are zeroing.
7. Write down the MOA value for the range at which you are zeroing. Using methods taught in Chapter 6, correct this elevation MOA setting to standard conditions from the MET and ENV conditions in which you are zeroing. Subtract the two MOA values. Determine whether you need to turn the knob up or down. Basically this is done by adding the MOA corrections to the superelevation MOA instead of subtracting them (if this would have been correcting for a shot) Once this is calculated, place this correction on the sight. This sets the true SACs zero setting for the night vision sight.
8. Loosen the screw holding the elevation knob and again slip the knob around to the value in MOA for the elevation setting you determined in step 7. You have now placed a SAC zero on the elevation knob.
9. Go to the windage knob and zero it.
10. Clean the rifle and reshoot to confirm the zero. Two groups of 5 rounds each will do.
11. Remove the night sight, re-install and torque the scope. Re-shoot and reconfirm the zero and record any deviation from the ON/OFF procedure. Do this three times. If the sight cannot keep a consistent deviation from the ON/OFF procedure, find a new sight. If this is not an option, do the process as many times as you have time and ammunition for and take an average deviation of the ON/OFF procedures.

It is very important to establish the repeatability of any day or night system. Few individuals, or military snipers for that matter, have the convenience of discarding a sight and getting a different one. The only way to get familiar with the repeatability of the sight system is repeated ON/OFF procedures designed to determine how much deviation happens when the sight is taken off and replaced. Again, if you cannot replace the sight and the deviation is not with 1/2 MOA in consistency, take the sight on and off several times, firing 5 shot groups each time and get an average deviation. Then record this as the best repeatability possible with that night vision sight.

It is quite possible that your sniper rifle may be a 1-minute rifle during the daytime. At night, when the night sight comes out and is installed that 1 minute capability becomes perhaps 2 1/2 or 3 MOA because of deviation experienced when putting the night sight on.

It is for this reason that military shooters and material developers have long sought a different solution to the problem of night sights for sniper weapons systems. After many years of snipers dealing with substandard systems such as the AN/PVS-4, and the mounting problems associated with them, a foreign company finally came up with another solution. This was the Kigre SIMRAD night vision sight and it is designed solely for use on sniper weapons systems. This type of system is called a "piggyback" night vision sight.

**ZEROING "PIGGYBACK" NIGHT VISION SIGHTS.
(SIMRAD, NVEC NADS-850, NADS-1000 MEDIUM AND LONG-RANGE SIGHTS)
GENERATION II, II+ AND III**



Within U.S. Special Operations Command the most common night sight used by far is the SIMRAD. This was never purchased and issued command-wide, but it can be found in different units here and there. There are three basic versions of the sight, and each has some peculiarities about it when mounting, zeroing, and shooting. All variations of this sight are mounted on top of the day optical sight. For the sake of this writing, let's assume that we are going to zero the sight on a rifle with the Leupold & Stevens Mark IV, M-3 10X scope.

The front mounting ring on the day scope is changed for a scope ring that has a very wide male dovetail in the top ring half of the scope ring. This is the attaching point for the night sight. It is recommended that a third lower half of a scope mounting ring be obtained and attached to the scope base, in effect having three mounting rings; one behind the elevation turret and two in front of the elevation turret. This adds a degree of stress to the scope as this 4.25 lb. sight is attached to the top of the day scope. In many cases it causes some deviation in the zero of the day scope when attached. Experience in the field has indicated that even when shooting during the day using the look-through lens on the SIMRAD a zero change occurs because of the stress of the 4.25 lb. night sight. All of the manufacturers of "piggyback" systems claim minimal deviation from attaching this sight, but experience says that it happens anyway. This must be determined, recorded and corrected for each and every time the sight is put on and removed.

Deviation from mounting also occurs when the top ring half used in mounting the scope isn't level to the rest of the gun. It is best installed using a ball indicator to prove level with the rest of the day sight system. Something else about the piggyback system is that you are essentially shooting at a TV picture of your target. The image is picked up and intensified by the night sight and then the image is reflected through mirrors and beamsplitters into the front of the day scope.

It is very important to know that the night sight is 3.5 inches above the line of sight of the day scope on the NVEC sights and 3.7 inches above on the SIMRAD. Because of this you have to zero the system

by accepting that your point of impact will always be 3.5 inches or 3.7 inches below your point of aim. If you adjust point of impact to point of aim with the night sight attached, you will induce huge zero error in the system. Your day scope zero will be totally off.

There are two basic models of piggyback night vision sights—with boresight adjustments and without boresight adjustments. The SIMRAD system by Kigre has three models of this sight:

Kigre SIMRAD KN200. This was the first model of this sight system. It is the larger of the two offered by Kigre. It is NOT advised for use on .50-caliber SWS. There are no boresighter adjustments on some of these scopes.

Kigre SIMRAD KN200 w/ boresight capability. This model of the same type sight has a capability for boresighting any deviation out of the night sight that occurs when putting it on the day scope. It works quite well when done correctly and with great care.

Kigre SIMRAD KN250. This night sight has no boresight capability. The factory claims that any deviation from mounting is corrected for at the factory. However, this does take into account any differences in mounting systems or the possibility that the top dovetail ring mount is exactly level with the rest of the rifle. It is possible to have cant in the SIMRAD because the top ring isn't exactly level with the rest of the gun.

Zeroing Piggyback Systems without Boresight Adjustments

1. We will begin the zero process by assuming that the operator has just installed the upper ring mount to hold the night sight itself. At this point, the entire rifle with day scope only must be rezeroed. Use the zero procedures outlined earlier in this chapter and the Day Scope Zero card at the end of this chapter.
2. Now we must determine the deviation that may be caused when simply attaching the night sight to the dovetail mount on the day scope. Open the look-through cover on the night scope and shoot a 5-round group at precisely the same target and point of aim used to zero the day scope itself. Not all systems will cause deviation, but most will.

Note and record in the space provided on the SIMRAD zero card the elevation and windage change that occurs after mounting the scope. This deviation has nothing to do with zeroing the night sight itself. This is only the first step in a two-step shooting process to determine the zero of the night sight and any deviation that may occur in the system. This can be done in the daytime.

These deviations for elevation and windage must be applied to the day scope when attaching the night sight. The author has seen snipers put as much as 4 MOA on the elevation knob and 3 to 4 minutes of correction on the windage knob. Obviously, this creates more problems for the team when indexing new ranges and windage changes.

SIGHT CHANGES FROM MOUNTING SIMRAD ON DAY OPTICAL SIGHT	ELEV + or -	WIND L-R

3. Under night conditions, using a recommended minimum of 60 percent ambient illumination (watch the news, or call the local airport for percent of illumination; for military guys check with S-2) ensure that you have followed all of the general rules above. Fire 5-round groups through the night system. Remember that your point of impact will be 3.5 or 3.7 inches below your point of aim. This is constant at all ranges. **DO NOT ZERO OUT THIS VERTICAL CHANGE!**

Theoretically, once you have zeroed out the deviation from attaching the night scope, there should be no change when you shoot through the system at night conditions. This may not necessarily be the case

because of the mirrors inside the night sight itself. You must determine if there was any deviation when shooting through the night sight.

If all goes well, there should be no change when shooting through the look-through portion of the night scope and shooting with the night sight turned on. If there is any deviation, you must record this also. It has been noted that there can be as much as a 2 minute change for windage and/or elevation when shooting through the night sight itself.

4. If you had deviation from steps 2 and 3, calculate the total deviation and this is the number that you must put in the box on the zero card. This will be your total day sight change when attaching a piggyback night sight to your day scope. You may also have any combination of the two situations above. There may be no zero change when attaching the night sight and shooting through the look-through lens on the night sight. But, when you go to shoot at night through the night sight itself, there may be deviation.
5. Determining repeatability is the final step in the technical process of zeroing a night sight. Remove the night sight from the day scope and then replace it and fire a 5-round group. If there is no change, do this 5 times for a total of 25 shots. If there is a change, determine if this change is consistent by removing and replacing the night sight and firing 5-round groups. If the change is inconsistent, take an average of the group deviations. This average is the best capability that you can expect out of your system. You may soon learn that you can only expect 2 or 3 MOA in repeatability. Combine that with a system capable of 1.5 MOA and your nighttime best engagement range is getting short.

Another kind of piggyback night sight has boresighting devices or adjustments attached. This allows the operator to attach the night sight and then adjust it to the day sight's zero, thus eliminating the need to correct for (on the day scope) any deviation from attaching the night sight to the rifle. There are a number of Kigre KN-200F sights that have boresighting adjustments on them. They are located just above the look-through lens on the bottom front of the night sight. These sights are big and heavy but do the job quite well. They are adjusted with a hex wrench.

Zeroing Piggyback Systems with Boresight Adjustments

1. As in the above instructions, we will assume that the operator has just installed the dovetail ring mount. Rezero the entire rifle with day scope only.
2. Now we must determine the deviation that may be caused when simply attaching the night sight to the dovetail mount on the day scope. Open the look-through cover on the night scope and shoot 5-round groups at precisely the same target and point of aim used to zero the day scope itself. Not all systems will cause deviation, but most will.
3. If there is deviation on the target, have the target puller determine the MOA correction needed to put the point of impact at the desired spot below the point of aim. Remember the vertical distance between point of aim and point of impact when using piggyback night sights. Make the necessary elevation and windage corrections on the boresighting adjustments on the front of the night sight.
4. Under night conditions, using a recommended minimum of 60 percent ambient illumination, fire 5-round groups through the night system. Remember that your point of impact will be 3.5 or 3.7 inches below your Point of Aim. This is constant at all ranges. **DO NOT ZERO OUT THIS VERTICAL CHANGE!** If necessary make further adjustments to the boresighter knobs after shooting through the night vision system not using the look-through lens.

If all goes well, there should be no change when shooting through the look-through portion of the night scope and shooting with the night sight turned on. If there is any deviation zero it out on the boresighting knob.

EXAMPLE

1. This is a recorded change from the day scope when attaching the SIMRAD night sight and shooting through the look-through lens on the night sight.

Sight changes from mounting SIMRAD on day optical sight	ELEV + or – –2 MOA	WIND L-R Left 1 MOA
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2. Further deviation from shooting through the night sight under full night conditions.

Sight changes from mounting SIMRAD on day optical sight	ELEV + or – –1 MOA	WIND L-R NO CHANGE
--	-----------------------	-----------------------

3. Total deviation from steps 2 and 3 in the zero process. This is the change that the shooter would put on his day scope when attaching the night sight and shooting under night conditions. It represents a total of changes from mounting and shooting through the night sight itself.

Sight changes from mounting SIMRAD on day optical sight	ELEV + or – –3 MOA	WIND L-R Left 1 MOA
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5. Determining repeatability is the final step in the technical process of zeroing the boresighter night sight. Remove the night sight from the day scope and then replace it and fire a 5-round group. If there is no change, do this 5 times for a total of 25 shots. If there is a change, this change must be corrected for on the day scope and NOT by changing the boresighting knobs. Determine if this change is consistent by removing and replacing the night sight and firing 5 round groups. If the change is inconsistent, take an average of the group deviations. This average is the best capability that you can expect out of your system.

ZEROING DAY/NIGHT COMBINATION SIGHTS (AN/PVS-10, ETC)

The combination day/night systems are the latest to hit the military inventories. These sights are a single sight element that combines both day and nighttime capabilities. It is the first sight system designed for sniper weapons systems. The AN/PVS-10 system has a BDC and windage adjustments similar to that of the day scope on the M-24 SWS.

There are two versions available. The first version is an 8.5X sight solely intended for the M-24SWS. The requirement stated that the day/night scope must be identical in certain characteristics that made it as shooter friendly as the L&S M3A Ultra scope on the gun. This meant a BDC, windage adjustments in 1/2 MOA, and full parallax adjustments. The new sight must not require the operator to take a different cheek weld on the stock. The new sight does all of that.

The second version of the day/night scope is a long-range sight intended for use on .50-caliber rifles. The heavy night sight has a ballistic drop compensator that is tuned for use with .50-caliber ammunition. Refer to Chapter 6. Remember that various ammunition has different flight trajectories. Which round the BDC is tuned for is not yet known. The heavy sight has a 12X magnification. Statements from a Litton representative said that in testing, shooters were able to get headshots at 600 meters at night. It was not stated the conditions and percentage of illumination in that test.

AN/PVS-10 SNIPER DAY/NIGHT RIFLE SIGHT

As with the M3A day scope that the night scope is intended to mimic in operation, there is no PBZ for the AN/PVS-10 either. It has a BDC the same as the M3A. However, as with the M3A you do correct to SAC zero. Below is the process for placing a SAC zero on the AN/PVS-10 day/night sight.

1. Determine the range at which you are going to set the SAC zero. This does not necessarily have to be on a KD range, but you do have to know to the nearest meter what the range is. It is suggested that the zero is executed at 300 meters. The longer the range the more precise the zero (out to 600 meters). Keep the winds in mind.
2. Determine and record the ENV and MET conditions as they exist.
3. Select and record the base ammunition type, for example: M-118 SB.
4. Establish the target. It is suggested that the NRA, Rifle, Target "A" is used.
5. Determine the point of impact desired on the target. Usually the "X" ring.
6. Fire 5-round groups and make adjustments so that POA and POI are at the same point. Do not slip any rings yet.
7. Write down the MOA value for the range at which you are zeroing. Using methods taught in Chapter 6, correct this elevation MOA setting to standard conditions from the MET and ENV conditions in which you are zeroing. Subtract the two MOA values. Determine whether you need to turn the knob up or down. Basically this is done by adding the MOA corrections to the superelevation MOA instead of subtracting them (if this would have been correcting for a shot). Once this is calculated, place this correction on the sight. This sets the true SAC zero setting for the sight.
8. Again, loosen the locking screws and rotate the knob once more to the range at which you zeroed (usually 300 meters).
9. Confirm the point of aim and point of impact are coincident by firing a group of five rounds.
10. You now have a SAC zero on the day/night sight. From this point on, if you dial a range on the scope, that setting indicates a trajectory that corresponds to SAC only. Remember to determine the corrections for ENV and MET and index them if you have time and the difference is significant.
11. Determining repeatability is the final step in the technical process of zeroing your day sight. Remove the day scope and then replace it and fire a 5-round group. If there is no change, do this 5 times for a total of 25 shots. If there is a change, determine if this change is consistent by removing and replacing the night sight and firing 5-round groups. If the change is inconsistent, take an average of the group deviations. This average is the best capability that you can expect out of your system. You may soon learn that you can only expect 2 or 3 MOA in repeatability.

ESTABLISHING AN INTEGRATED SHOOTING SYSTEM FROM THE BEGINNING

For the civilian shooter who happens to shoot a heavy-class rifle and loads his own ammunition, there are solutions too. When a rifle is first built, a precision load is developed for it. This is based on a certain bullet, or bullets, powder, primer, and case. It may also be based on commercially developed ammunition such as that offered by Thunderbird Cartridge. The following is a description of the process involved in developing an Integrated Shooting System (ISS) based on an individual's desire for a total rifle system.

- An individual expresses a desire for a custom heavy rifle. For the sake of this discussion, let's say he wants a .50-caliber rifle to be used as a sniper rifle and as a competition rifle for training. He may know what action, barrel, and stock combination that is desired. If not, a builder will pull out the books and they will settle on the components desired. In this example, we have chosen the McBros Action, a K&P Barrel by Ken Johnson, and a McMillan fully adjustable stock.

- Because the rifle barrel has to have a certain twist rate, they would discuss what the shooter wants from the rifle. This may be better long-range characteristics (heavier bullets) or a flatter trajectory over a shorter range (lighter bullets). These bullets' weights somewhat drive what twist rate will be used in the gun.
- Now that we have the basics for the rifle, construction can begin. It may be conventionally bedded or barrel blocked. Once the rifle is finished, it is proof test-fired with a high-pressure cartridge to ensure its strength. At this point, a precision load must be developed for the rifle.
- Through load testing, we have determined that using 239.1 grains of Vihtavouri 20N29 powder, CCI35 primer, a commercially available match grade case, and the 647-gr. Speer bullet yielded the best result. Note that we haven't chronographed this load yet. We only developed the most accurate load possible using the desired components.
- Now we are going to do the ballistic development of the rifle and cartridge combination. This is a very involved process that requires careful recording of data.

This data includes:

- Air temperature
- Barometric pressure
- Ammunition temperature
- Angle of gun to target (if any)
- Initially, we are going to chronograph and record the muzzle velocity of the cartridge that we have developed. This will be done at 15 feet past the muzzle and corrected to the muzzle velocity itself. Through a mathematical process we will determine the ballistic coefficient for this rifle/cartridge combination at the muzzle. Note that we do NOT use the listed ballistic coefficient as offered by Sierra. This is because that number is based on a test barrel. That BC does not necessarily equate to your gun/ammo combination.
- We will then fire rounds and chronograph them at 100, 300, 500, 700, and 1,000 yards, greater if possible. We will record the remaining velocities and then determine the downrange ballistic co-efficient for your rifle and ammunition combination. Once we have all of the downrange BCs determined, we will correct these to SAC. These conditions are 59 degrees. F, 29.93 In. Hg, sea level, and 70 degrees F. ammunition temperature.
- Now that we have the BCs determined, we can calculate the data tables for your rifle and ammunition package. These tables are a set of tables from 0 to 2,500 meters (.50 caliber) that tell you exactly where to set the elevation on your sights. How this process is done is too lengthy for this document.

Now the shooter has a rifle that is built to his specifications, with ammunition tailored to that rifle and with a set of data tables that were developed from that rifle's load combination. The only missing component is the optical and iron sights (if desired) and the integration of these into the system.

Explanation of Parallax

Parallax is caused by the image projected by the objective lens system focusing either in front of the reticle or behind it. When the image is focused on the reticle you are parallax free. You know you have parallax when you move your head around in the field of view and the reticle moves off your aiming point. Adjustable objective (AO) scopes will focus the image exactly on the reticle and eliminate parallax errors. Non-adjustable objective scopes are preset at one distance, usually 150 yards.

Parallax may be reset to a distance you feel is more appropriate, if necessary. Rule-of-thumb we use is to first determine the maximum distance you will shoot. From that distance deduct 20 percent. This would be the best

parallax setting. You might do this if you wanted to set-up any non-AO for rimfire. This can include any compact or full-size scope. It could be set to 60 yards or any other distance you feel more appropriate. This may be done on ANY non-adjustable objective Leupold scope. Some adjustable objective scopes can have the focus modified so they can focus in to slightly looser distances. If a 6.5X20 40mm AO, 8.5X25 40mm AO or 12X AO was modified to focus down to about 25 yards, the maximum distance would become about 100 yards. Resetting the focus less than 25 yards is not recommended because maximum focus capabilities are seriously limited.

You should be aware of the influence of temperature variations on any scope with or without an adjustable objective scope. The lens spacing on any scope will change as the temperature changes because the scope tube is aluminum. When the parallax is originally set it is done at room temperature. If your scope has an adjustable objective and you find the setting reading different than the actual distance it is not reason for concern. You can be certain parallax is set properly when you move your head in the field of view and the reticle does not move relative to the aiming point. It doesn't make any difference if the scale reading is off.

PRECISION ZERO CARD – DAYTIME OPTICS HEAVY RIFLE

WEAPON AND SERIAL NUMBER

OPTICS ON/OFF ZERO CHANGE:

Name:		Location:	
Barometric Pressure:		Air Temperature:	
Ammunition Temperature:		Slant Angle To Target:	
WIND CONDITIONS FROM:		VELOCITY:	
RANGE TO TARGET:			
BASE AMMO TYPE: Example: Mark 211, Mod-0 and Lot #		Mark 211, Mod-0 #123-456-789	
1. REFERENCE ELEVATION SETTING FROM DATA TABLE Example: 13.75 MOA for 500 meters			

USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD ATMOSPHERIC CONDITIONS. ADD TOTAL OF CHANGES.

2. TOTAL OF CHANGES FROM MET AND ENV CONDITIONS	+ or -		MOA
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1. BULLET DROP COMPENSATORS: Shoot and adjust Point of Impact to Point of Aim. Slip the BDC ring to the range value for the range you are zeroing the rifle. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.). Re-slip the BDC ring to Range value.

2. RAW ELEVATION KNOBS $\frac{1}{4}$ or $\frac{1}{2}$ MOA. Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) Slip elevation knob to the MOA value determined in steps 1 and 2.

ZERO DEVIATIONS FOR OTHER AMMUNITION			
TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API			
M-20 API-T			
M-33 Ball			
M-17 Tracer			
M-903 SLAP			

Military snipers are the best example of how to use this block. We might zero with Mark 211, Mod-0, M-33 Ball, M-8 API, M-20 API-T or SLAP ammo, Tracer ammunition, commercially purchased Federal Match, or any hand-load that we might dream up. These will all deviate from the base ammo point of impact. Record these changes in elevation and windage, so they may be applied when necessary.

Always record the MET and ENV data. A zero without this data isn't worth anything

Never ignore any winds on the range when zeroing the rifle. Any wind affects the flight of the bullet.

Record the base ammunition that you are zeroing with. Enter the Lot #.

Book II, Sect. II, Chap. IV, for reference.

Book II, Sect. II, Chap. IV for reference.

WHAT TO DO WITH THE DATA.
BDC scopes get adjusted twice. After zeroing POI to POA, you slip the ring to the range you are zeroing at. Example "3" for 300 meters. Then click the scope up or down for MET and ENV corrections. Finally, re-slip the BDC ring to the range. You now have a Standard Atmospheric Condition zero on the gun.

Scopes with $\frac{1}{4}$ or $\frac{1}{2}$ MOA knobs simply get corrected for MET and ENV conditions and then get slipped to the MOA value for the range they are shooting at.
Ex: 13.75 MOA f/ 500M

SIMRAD or other PIGGYBACK NVD ZERO CARD

ZERO CARD – SIMRAD NIGHT OPTICS HEAVY RIFLE			
WEAPON AND S/N:		NIGHT OPTICS S/N:	
SIGHT CHANGES FROM MOUNTING SIMRAD ON DAY OPTICAL SIGHT	ELEV + or -	WIND L R	
Name:		Location:	
Barometric Pressure:		Air Temperature:	
% Illumination LUNAR		Cloud/Haze Cover/Obscure	
Ammunition Temperature:		Slant Angle To Target:	
WIND FROM:		VELOCITY:	
RANGE TO TARGET:			
BASE AMMO TYPE:			
Example: Mark 211, Mod-0 and Lot#			
1. REFERENCE ELEVATION SETTING FROM DATA TABLE			
Example: 9.50 MOA for 300 Meters			
USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD ATMOSPHERIC CONDITIONS. ADD TOTAL OF CHANGES.			
2. TOTAL OF CHANGES FROM MET AND ENV CONDITIONS		+ or - MOA	
1. BULLET DROP COMPENSATORS: Shoot and adjust Point of Impact to Point of Aim. Slip the BDC ring to the range value for the range you are zeroing the rifle. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.). Re-slip the BDC ring to Range value.			
2. RAW ELEVATION KNOBS $\frac{1}{4}$ or $\frac{1}{2}$ MOA: Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) Slip elevation knob to the MOA value determined in steps 1 and 2.			
ZERO DEVIATIONS FOR OTHER AMMUNITION			
TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API			
M-33 BALL			
M-20 API-T			
Use only one type of ammunition for shooting at night and zero with that ammunition. For military snipers, go with the M-118 and avoid the match stuff. There is nothing wrong with using others rounds for emergencies. For example, using tracers to mark a target in an emergency is fine.			

Since SIMRAD sets on the day scope, any sight changes that occur from this mounting must be recorded. Some SIMRADs have bore-sighting adjustments for this, but the majority does not.

Note the blocks for illumination and for cloud cover. Rain, fog, haze can also go here. This all affects how much range you will have with the NVD sight.

Just as with setting the MET and ENV changes on the scope during the daytime, you must also index them at night. Put these changes on the day optic, not the night scope.

This data is applied the same as with the Day optic.

ZERO CARD – DEDICATED NIGHT OPTICS SYSTEMS – RIFLES
STAND ALONE NIGHT SIGHTS – EX. AN/PVS-4, AN/PVS-7, AN/PVS-14

WEAPON AND S/N:

TYPE NIGHT AND OPTICS S/N:

MAXIMUM EXPECTED ZERO REPEATABILITY ON/OFF OF NIGHT SITE		ELEV + or -	WIND L-R
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Name:		Location:	
Barometric Pressure:		Air Temperature:	
% Illumination LUNAR		Cloud/Haze Cover/Obscure	
Ammunition Temperature:		Slant Angle To Target:	
WIND FROM:		VELOCITY:	
BASE AMMO TYPE: Example: M-118 and Lot #			

ZERO DATA

ZERO RANGE: For NVDs without trajectory compensation capability, use a "Reverse Image Zero".	
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CORRECTIONS FOR MET AND ENV CONDITIONS
USE THE CALCULATIONS CARD AND DETERMINE THE
CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD
ATMOSPHERIC CONDITIONS. ADD TOTAL OF CHANGES.

TOTAL OF CHANGES FROM MET AND ENV CONDITIONS	+ or -	MOA
---	--------	-----

ADJUSTING ELEV AND WIND KNOBS ON NIGHT SIGHT. Shoot
and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from
MET and ENV conditions (2.) from the reference elevation (1.) Add or subtract
any changes based on MET and ENV on the night sight.

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API			
M-20 API-T			
M-33 BALL			
M-17 TRACER			
M-903 SLAP			

Changing ammo with dedicated systems is not a good idea. It is usually not easy to
index the zero deviations. If you cannot mechanically index the changes, write down
the best visual estimation for a correction. EX: "a little right and a little low". ☺

This information is
about the change
that occurs from
taking off the day
scope and replacing
it with the night
sight. The problem
here is sometimes
this change is
consistent, and
sometimes it is not.

This is the Range at
which you zero the
system. If you
choose to use a
Reverse Image
Zero, enter that
range here and that
it is a RIZ zero
method. Remember
to zero at the
"hard" range, not a
sub-caliber range.

Once you have the
scope zeroed for the
conditions as they
exist, you must
correct for MET
and ENV
conditions. Index
these changes ON
THE night scope's
Elev and Wind
knob. Some of the
dedicated scopes'
adjustment knobs
are very coarse. 1
MOA adjustments
are common.
Round off to the
nearest MOA value.

CHAPTER 6

Determining and Correcting for Meteorological and Environmental Conditions

Sniping ranges associated with the heavy-class rifles are likely to be in excess of 1,000 meters. At many engagement ranges, the sniper can ignore the effect of some of the MET and ENV conditions. The effects of air temperature, barometric pressure, altitude above sea level, and barrel twist do not really become a factor until shooting past 600 meters or so. Using the large bore .50 caliber rifles over a long range such as 1,400+ meters requires that all of the MET and ENV factors be addressed, corrected for, and placed on the sight system.

The intent of this chapter is to allow the military sniper to employ his heavy-class rifle anywhere in the world, under any ENV or MET condition. Special Operations snipers will not have the opportunity to zero their rifles in their target operational environment. In military terms this area is called the Joint Special Operations Area (JSOA) or the Special Operations Area (SOA). The JSOA or the SOA may be hundreds or thousands of miles from the base that he launches from. The means of infiltration may be from a freefall parachute drop or a landing with Zodiac small boats. In any case, the MET and ENV conditions most likely will not be the same as the area where the mission planning and mission rehearsals were done. You cannot pre-create the ENV and MET conditions for a rehearsal.

The driving force that eventually resulted in this book was searching for the answer to the question “How do I determine these factors, and more importantly, how do I correct for them?” When I attended the Special Operations Target Interdiction Course (SOTIC) at Fort Bragg, my partner at the time (who wishes to remain anonymous) and I worked out the mechanical problems associated with shooting the big guns. These have been refined somewhat with experience and time. After SOTIC I left and went back to Okinawa and my team with 1st Battalion, 1st Special Forces Group.

Because of the operational tempo and a lack of ranges on Okinawa my pursuit of this subject was limited to reading the limited (read: non-existent) material on the effects of MET and ENV conditions involved in shooting rifles. The material was out there. It just wasn't in a form that I had found and related to the shooting of shouldered-fired weapons. It wasn't until I was stationed at Fort Bragg and my subsequent assignment to the SOTIC committee that I had the opportunity to dive deeper into the search from the answer to my question “How much?” This next statement is what I call the “make me rich comment.” If I had a nickel for every time that I heard this statement, I would be millionaire now. It goes something like this:

“You don’t need to worry about this crap, you can shoot right through it.”

Uh-uh. I don’t think so. One of the drivers behind this statement being made is that many of these shooters have never tested themselves to the extreme ranges of 1,500 meters or more. One individual that made that statement was trained at a facility that only shot to 1,000 yards. Then he was transferred to Okinawa. No sniping missions other than training on Okinawa. The shooter that has never shot past 600 meters, in all likelihood, has never had to correct for MET and ENV conditions except for the temperature of ammunition. Then he probably wondered why the zero was a minute or two low. I would wager that a miss or two had resulted in some head scratching that was based on “where’d that bullet go?” The intent of this chapter is to clear up most of the mystery and give you the solid mechanics to shoot in different MET and ENV conditions.

Civilian and military shooters compensate for these effects by using shooter’s logs. These logs are a record of each and every bullet fired in practice and competition. These books contain many different bits of information: The location of the range, the wind and its direction on each shot, the air temperature, altitude, position of the sun, and any other piece of information that the shooter cares to enter in the book. These shooters then have a reference so they can refer to this data for some insight as to a correction to place on a sight. To be honest though, few refer back to these bits of data. Master class and high masters do, but not too many other shooters. The problem with this technique is that these competitions happen at the same places over and over. A special operations sniper, will NEVER be in the same place again. And if he is, it is highly unlikely that the MET and ENV conditions will be the same.

I remember the first time I fired a shot at a target that was farther than 1,000 meters. My partner and I were standing on the target berm on Range 66D, Fort Bragg. We were looking into the impact area where there were several metal targets. These included several large dumpsters and an old tank. We had a Daisy Model 600 .50-caliber rifle and a couple of AMAC 500s that a couple of Navy shooters had with them. We had a laser range finder (back before we learned to loathe them) and we took a careful laser shot at the target. The range showed 2,230 meters. We had a data book with some preliminary elevation setting for ranges only, no ammunition specific information, and we dialed in the elevation setting for 2,230 meters. Boom. We overshot by a huge amount. Long yards past the target. We all scratched our heads again. Hmm. What do we do now? I knew that the air temperature had a lot to do with it. It was 100+ degrees outside. We were firing on about a 6 degree slope. This was good for about a mere 12-meter error in range.

We did what many other shooters do in that situation. We dialed in an elevation setting correction based on some discussion and shot again. Still long. Eventually after a couple of corrections, we started putting rounds on steel. Impressive, lots of grinning and yelling. Yeah, we hit it after about 15 sighter shots. Not very impressive, I thought to myself. That was early in 1989. From that point on my marriage suffered great stress as my partner and I (he later dropped out of the research) started burying ourselves in books and the search for other books on exterior ballistics. Many phone calls were made to Aberdeen Proving Grounds and NSWC, Crane. Soon after that the calculators came out and some hard number-crunching began that lasted for several long months. This went on each and every night, for hours.

In long-range unknown distance shooting, there is absolutely no room for guesswork. Certainly in the field of military and civilian sniping, experience levels vary. One would think that the military targets of high priority would receive the attention of the best shooters. Well for very high level targeting that may be true. At the unit level, it’s luck of the draw, or more exact, it’s not what you know, it’s who you know. The use of firing tables and correction constants make the normal pattern of guesswork a thing of the past. It’s tough work, no doubt. When done correctly, the results are amazing and fun to see.

Remember that the focus of this book is Hard-Target Interdiction. The engagement ranges are almost always in the range that require careful determination and correction for the MET and ENV conditions. We are going to examine a shooting problem where all of the air conditions are other than standard (which is usually the case). Listed below is an example of the factors for which we correct. Here is the operational environment.

- Rifle: .50-caliber sniper rifle
- Type of target: surface to surface missile: 5.5 meters tall
- Range to the target: 1,600 meters
- Type of ammunition: Raufoss .50-caliber or Greentip
- Slant angle to the target: 10.75 degrees downhill (round will strike high).
- Air temperature: 75 degrees F (round will strike high)
- Barometric pressure: 24.56 In. Hg (round will strike high)
- Ammunition temperature: 100 degrees. F (round will strike high)

We are using the .50-caliber rifle. Many people think that these rifles shoot very flat, but this is not true. The .300 Winchester Magnum has a flatter trajectory over 1,000 yards and stays supersonic for a greater range depending on the load. The advantage of the .50 caliber is a greater and more destructive payload. In this case all of the conditions would indicate an environment that would cause the round to strike high on the target. But how high? Through the mathematical process, we determine the correction and therefore can thereby calculate the error. In the above case the error is a difference of 21 MOA. If we had fired the shot and not corrected for the conditions as measured the bullet would have traveled almost 33 feet above the point of aim. If the point of aim were the center of the missile the shot would go almost 24 feet over the target. The observer would not even see the trace of the bullet. He would also not see the impact of the bullet, as it is so far downrange. In fact, the round will fly 24 feet over the target and travel 293 meters downrange. An observer would not see the flight of the bullet.

This is a terrible error. It sounds too big to be true, but it's not. Lots of shooters rely on Kentucky windage—taking a wild guess at the winds and the range. This method has shown to be accurate in the mind and hands of an experienced shooter. I would say this, however. Do any Kentucky windage shooters reading this honestly believe that they would have “guessed” at a 33-foot hold-under on this target?

Should you choose to read this chapter and follow the walk-through instructions contained here you will be able to do the following:

- Determine correction for slant angle from the shooter to the target.
- Determine and correct for barometric pressure changes from standard.
- Determine and correct for ambient air temperature.
- Determine and correct for changes in the ammunition temperature.
- Determine the correction required for spin drift.
- Calculate an initial and final sight setting for windage and elevation.
- Determine your maximum effective range.
- Determine if you are indeed close enough to the target for a maximum effective range shot on the target.
- Place all of these corrections on the telescopic or iron sight on the rifle.

When I started to study ballistics I found many a reference to a book called *Artillery Circular “M.”* The more I ran across this reference, the more I tried to find a copy of this book. I was running out of patience and luck until I talked to the United States Army Special Warfare Center and School librarian, Fred Fuller. He receives the credit for aiming me in the direction that eventually was the solution. Fuller researched and found 6 copies of this long out of print War Department manual. *Artillery Circular “M.”* was printed in 1917. The author of Table I and II was Col. James Ingalls. These became known as Ingalls' Ballistic Tables. Col. Hamilton updated these tables in 1934. *Artillery Circular “M.”* was a schoolbook for artillery and naval gunnery officers. These officers had to calculate using pencils, paper, and slide rulers. They did the math at logarithmic scale. What we use Hewlett Packard scientific calculators for, they did with paper and pencil. When I looked at this book for the first time my jaw dropped. Ninety-five percent of these books are nothing but pages and

pages of rows of numbers. It was apparent that although I could use scientific calculators I would still need a basic knowledge of geometry and trigonometry. I thought back to the last time I had formal training in mathematics. It was scary. The last time was basic math in the 9th grade of high school, Ellendale, North Dakota. I realized that I was in hell. I began to read the book. Now, the style in which scientists wrote at that time was interesting. Half of the struggle was in trying to understand what they were trying to say let alone understand the technical explanations they gave. I used a formula from *Artillery Circular "M"* to derive a ballistic coefficient from downrange velocity.

There were formulas for determine departure angle, angle of jump, drift correction, and even the rotation of the earth. What was departure angle? What was angle of jump? What on earth was drift correction? Rotation of the earth I understood. Sure, the earth turns round and round. What amazed me was that while the projectile is in flight, the earth moves a certain distance under that projectile and flight. Fortunately this applies to high angle trajectory fire only. It is largely for artillery and naval gunfire. I couldn't imagine having to calculate the decay of a bullet in flight for 1,500 meters. After about a year I understood the formulas and how the tables worked. I understood that they were two entry tables for the most part. All I needed was ballistic coefficient and muzzle velocity of the weapons and ammunition. That seemed simple enough. It wasn't, as no one was recording this data except elements of the U.S. Government and they weren't too willing to give it out at the time. Again NSWC, Crane came through and provided data on velocities from .50-caliber rifles that they were testing. I won't say what these systems were at the time. We were using the same guns. There were small differences in velocity between manufacturers but they all were pretty close.

In my time in the U.S. Army and in Special Operations I have heard many shooters make the statement, "I don't need to know how it works, I only need to know how to make it work." On many subjects, I would agree with this statement; in the field of sniping, however, I would disagree totally. Everyone that has served in the U.S. Special Forces shakes their head when they think of all of the technical details that they need to remember to perform their missions. Obviously, they cannot remember and master them all. In the field of sniping, to ignore the details and focus only on training on the "major points" would certainly lead to mission failure. Previous to Desert Storm, I wrote an Estimate of the Training Situation for a possible deployment of the SOTIC committee to the Middle East. To support the committee's deployment I wrote this estimate of the capability of Special Forces snipers in a desert environment. In short, I predicted that their performance would be poor. This is not intended to slight the dedicated shooters out there. The major problem is a lack of command interest and influence. Commanders in SF and the Rangers at all levels do not pay attention to snipers or their training.

The sniper performance in Desert Storm was indeed dismal. The USSOCOM solution was not to focus harder on sniper training or why there was a lack of training. I was the NCOIC (non-commissioned officer in charge) at the SOTIC committee, and they never called us. They decided to throw money at the problem with development of "sniper technology." One of the ideas is a project called White Feather. I assume this is in reference to Carlos Hathcock. I doubt that Carlos would have agreed that technology is a solution to a training shortfall. White Feather is a study into technological support systems for the sniper. These include MET condition detection equipment (laser beams), laser range finders, inertial reticle systems, and triggers that enable the rifle to fire when the computer thinks all is OK. There were no solutions offered that I know of on how to improve training.

This brings us to the crux of this chapter. Mathematically correcting for the key MET and ENV conditions is the only way to move the circular capability of the gun into the center of the target. Remember this phrase. It is important to know and remember that a gun cannot fire to a precise point on a target. I have seen many shooters stare in wonder when a shot is two inches off center at 200 yards. They have forgotten that the gun can only fire to a "circular capability." What does this mean? It means that a bullet doesn't fly on a precise line to the point of impact on the target. Guns fire groups of shots that are randomly scattered on the target.

At SOTIC, 1st SFGA and at the SOTIC at Fort Bragg, we had a 2-MOA standard on all targets. What

this means is that on any target engagement, at any range, with any given scenario the smallest target presented will not be smaller than 2 MOA in size. When shooting headshots in snap engagements, the maximum range is 400 yards. The human head is approximately 8 inches across and a little taller. This is not smaller than two MOA. The moving targets used are standard “E” type military silhouettes. They are reduced in size to 9 inches across.

The maximum range of engagement for moving targets is again 400 yards. The instructors trained to a range of 600 yards on 9-inch movers. This was an instructor standard and therefore higher than the standard for students. The key point to remember in the chapter is that you are correcting for these conditions so that your 2-MOA circle is always superimposed over the center of the target. If you did not compensate for these effects, this circle could possibly be slightly off center or high or low. It is possible for the 2 MOA circle to be completely off the target as in the previous example. Now, with the explanations out of the way, let us proceed with this most interesting aspect of long-distance shooting.

INTRODUCTION TO THE THREE BALLISTIC ENVIRONMENTS

The term “firearms ballistics” refers to the discussion of the mechanics of firing a projectile through the atmosphere to a point that you want it to impact. This includes the mechanics of the firearm once the trigger is pulled, through primer ignition, powder ignition, the bullet traveling down the barrel, the bullet in flight, and the bullet’s contact with something (not necessarily the target at which you are aiming). The three ballistic environments are:

1. Internal ballistics
2. External ballistics
3. Terminal ballistics

The first ballistic environment is that of internal ballistics. Essentially we use the term internal ballistics because it deals with everything inside the firearm. For the sake of definition, let’s call internal ballistics that part of ballistics that deals with the firing of the projectile down the bore inside the firearm. From the pull of the trigger, the release of the sear, the striking of the firing pin, the ignition of the primer and propellant, the projectile moving down the bore, and up to the point at which the bullet leaves the muzzle of the barrel.

Other areas include the chamber pressure, lock time and headspace. In relation to this chapter, interior ballistics deals with changes in muzzle velocity due to hot or cold ammunition.

The second ballistic environment is that of external ballistics. The science of external ballistics regards the projectile in flight once it has cleared the muzzle of the rifle to the point at which it impacts the target. To understand the methodology of correcting for MET and ENV conditions, you must understand some basics about exterior ballistics.

The third ballistic environment is that of terminal ballistics. The study of terminal ballistics is concerned with the path of the bullet and its effects once it makes contact with any medium other than air. This ranges from what happens to the bullet to wound ballistics of the target itself.

The majority of discussion in this chapter is the area concerning external ballistics. The factors you correct for exterior ballistics have the greatest effect on the flight of the bullet in comparison to the other two environments. Not to be ignored is interior ballistics because you will correct for ammunition temperature. This is the one correctable factor that has definite short-range effects on the flight of the bullet. All the properties of external ballistics affect the flight of the bullet over the longer range. You must understand some of the terminology used in basic ballistics when discussing correcting for MET and ENV conditions.

MUZZLE VELOCITY. This is the speed of the bullet as it exits the muzzle of the rifle. This data is usually measured at a set distance downrange from the muzzle. The actual muzzle velocity is calculated and

corrected from this point. It is important to know the muzzle velocity data that you examine has the distance of the measurement from the muzzle data available. To develop firing tables from the Ingalls Ballistic Tables you must have a measured muzzle velocity for your rifle and load combination.

TRAJECTORY. This is the actual path that the bullet takes once it has left the muzzle until impact with the target or another medium. External ballistics is the study of these phenomena. Within the trajectory are the following components.

Rising Branch. This is the part of the trajectory where the bullet departs the muzzle of the rifle and “rises” (when the muzzle is elevated) in flight until it reaches the maximum ordinate.

Mid Range Trajectory (MRT). This is the height the bullet reaches at the true midrange to the target. For example on a 1,000-yard shot, the MRT occurs at exactly 500 yards. This term is frequently confused with maximum ordinate.

Maximum Ordinate. This is the highest point the bullet reaches along its trajectory. It is measured from the line of sight as you look through the sights to the target, not from the ground or from the line of bore. It occurs at different ranges with different cartridges and weapons. Maximum ordinate will never occur before the MRT. Reviewing the data book will indicate that the maximum ordinate occurs farther than the MRT as the range increases. Maximum ordinate will be the focus of much field firing during this sniper course.

Falling Branch. This is the part of the trajectory where the bullet has reached its maximum ordinate and is now beginning its downward flight to the target. This terminates at the target or any other medium.

LINE OF BORE (LOB). This is an imaginary line measured in degrees and MOA that the barrel is elevated to send the bullet traveling to the target.

LINE OF SIGHT (LOS). This is the sight line of the shooter through the optical or iron sight system to the point of aim. This is often confused with the line of bore.

BALLISTIC COEFFICIENT (BC). This is a numerical definition of the ability of a bullet to resist air drag. It is based on a simple relationship between the bullet's length, weight, shape, diameter, and velocity at a point downrange. This BC number is stated as a comparison to a “perfect bullet.” That bullet is assigned a value of 1.0000. Refer to the firing tables for the Mark 211, Mod-0 cartridge. At the bottom of the table, the printed ballistic coefficient is .6001. You should know that this is an average of over 2,500 meters. This includes transonic and subsonic flight, both of which affect the BC radically. The true ballistic co-efficient (or flight co-efficient as it used in these custom tables) changes based on the muzzle velocity of the gun and when plotted on a curve, resembles a sine wave when compared to the BC values as the bullet travels downrange. The BC numbers start out high and drop off as the bullet approaches transonic flight. At subsonic flight (immediately after transonic flight) the BC is at its lowest point. As it travels even further downrange and stabilizes after its transonic disruption, the BC numbers begin to climb again.

FALL ANGLE. The fall angle is the degree of arc that represents the trajectory of the the bullet as it impacts the target. This is also referred to as the striking angle.

FLIGHT TIME. This is a bullet's time of flight in milliseconds from the muzzle of the gun to the target. This data is used in determining many technical factors. We will stress the use of this to determine if there is enough time for the bullet to travel to the target before the target bobs out of view. This may be because the target is a radical mover and cannot sit still, for example.

REMAINING VELOCITY. This is the bullet's velocity when it impacts the target. This is also known as the impact velocity.

GYROSCOPIC PRECESSION. This is the motion that a bullet has when it is in flight. Sometimes this effect is minimal and sometimes it is so bad as to have a negative effect on the flight of the bullet. It is likened to a quarterback's pass. Sometimes it flies perfectly along its trajectory with no coning motion. Other times it has a pronounced wobble that bleeds off energy and range faster. This has many causes. One of the common causes in military ammunition is the core of the bullet not being precisely located in the center of the bullet. This effect does stabilize with range. It is a common reason that some rounds will group poorly at close range and get better as the range increases.

In the preface of this book, I stated that the intent of this book is threefold. First, it is for the military shooter that wants to expand his base of knowledge. This shooter would be unsatisfied with what he has learned in other schools and wants more information. Second, this book is for the serious civilian shooter that wants a look into the inner-circle training methods of special operations sniping. Admittedly, some will scoff at the language and direction of this book. To many in the military this book will appear arrogant and self-serving. It is intended as neither. I feel that a professional sniper must know his capabilities. He would explain what he can do, not what he cannot do. In telling someone this, it will indeed sound arrogant. Lastly, this book is intended to provide a needed push in military sniping. It is intended as a reference material for the graduate student of military sniping. There are many schools on basic sniping, both military and civilian. There are no schools on Hard-Target Interdiction, and there are very limited schools on VIP countersniping.

To this end, this chapter begins the discussion of the very scientific art of trajectory correction. These tables represent a mathematical process that eliminates any guesswork. To the military sniper that understands that there are no shooter's logs for a target "In the middle of nowhere, in whatever country," this chapter and book offers the solution. Because there are so many calibers and types of ammunition in use, the tables used in this chapter are for one type of ammunition, the Mark 211, Mod-0 round of ammunition for the .50-caliber sniper weapons system in the SOF inventory. This round is standard in Naval Special Warfare and the U.S.M.C. It is found sporadically in the Army where the subject has been given mere lip service formally. This is mainly intended for the military sniper, but it offers a unique insight into a very small circle of special operations snipers—only about 60 people have received training in these methods. Certainly they are some of the most dangerous long range unknown distance snipers on the earth.

To be able to understand this chapter, one must be totally familiar with Chapter 5, "Sight Adjustment and Zero of the Heavy Rifle." In that chapter, the mechanical and mathematical processes of zeroing the rifle were explained. There was an introduction to the firing tables in this chapter as well. Before proceeding with this chapter, take some time to manipulate the sights as I have discussed in that chapter. For the military shooters with the M3A, M1A, Swarovski, Hensoldt, or Unertl scopes, have your optical sights with you as you read this chapter and become familiar with the firing tables used in this chapter. The words and numbers can be hard to follow if you do not practice "indexing" these numbers on your iron and optical sights.

INTRODUCTION TO THE FIRING TABLES

As I stated above, the tables used for the training involved in this chapter are based on the Mark 211, Mod-0 military cartridge. This cartridge has a 653-grain high-explosive armor-piercing, incendiary projectile. It is a full metal jacket, boattail bullet. The weapon used by the U.S. Navy and some of the other armed services include the Barrett Light .50, Daisy M600, AMAC, M500, different McMillans, and some very special custom pieces here and there. These tables are based on muzzle velocities measured when using Mark 211, Mod-0 fired out of a specific type of .50-caliber SWS. They are precisely tailored for use with these rounds of ammunition and weapons.

The following are extracts of .50-caliber data firing tables that contain the detailed corrections for a specified .50 SWS firing the listed round of ammunition. In this chapter's examples, we will use the Mark 211, Mod-0 ammunition table.

This first table is called a "Primary Functions" table because it contains that primary information the sniper requires to ensure a high probability of hit or kill at different ranges. This data deals with elevation changes and constants that will be used to correct for BP and air temperature effects on external ballistics.

BALLISTIC DATA
MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL.AMMUNITION

RANGE	SUPER ELEV-MOA	SUPER ELEV-MILS	SUPER-ELEV. PER 100 METERS	TEMP. CORRECTION FACTORS	BAROMETRIC CORRECTION FACTORS	ALTITUDE CORRECTION FACTORS	REMAINING VELOCITY
100M	2.25	0.65	2.25	1.00000	1.00000	1.00000	2674 FPS
200M	4.75	1.40	2.50	1.00000	1.00000	1.00000	2514 FPS
300M	7.50	2.20	2.75	1.00000	1.00000	1.00000	2359 FPS
400M	10.50	3.10	3.00	1.00000	1.00000	1.00000	2210 FPS
500M	13.75	4.10	3.25	1.00550	1.00000	1.00000	2067 FPS
600M	17.50	5.20	3.75	1.00593	1.01026	1.00855	1929 FPS
700M	21.25	6.30	4.25	1.00638	1.01214	1.01043	1798 FPS
800M	25.50	7.60	4.25	1.00761	1.01482	1.01236	1673 FPS
900M	30.50	9.00	5.00	1.00910	1.01715	1.01514	1554 FPS
1,000M	36.75	10.90	6.25	1.01059	1.01914	1.01661	1442 FPS
1100M	42.75	12.70	6.00	1.01271	1.02228	1.01890	1337 FPS
1200M	49.25	14.60	6.50	1.01430	1.02479	1.02125	1240 FPS
1300M	57.75	17.10	8.50	1.01598	1.02781	1.02373	1153 FPS
1400M	67.50	20.00	9.751	1.01782	1.03046	1.02660	1080 FPS
1500M	78.50	23.25	11.00	1.01914	1.03299	1.02911	1024 FPS
1600M	89.25	26.40	10.75	1.02035	1.03510	1.03145	986 FPS

BULLET WEIGHT = 651 GR. / BALL. CO-EFFICIENT AVERAGE = .6001
 AVERAGE MUZZLE VELOCITY = 2840 FPS AT THE MUZZLE
 CONDITIONS: 59 DEG. / 29.53 In. Hg. / 0' ASL / 70% HUMIDITY

PRESSURE UP - MULTIPLE BY CONSTANT
 PRESSURE DOWN - DIVIDE BY CONSTANT
 TEMP. UP - DIVIDE BY CONSTANT
 TEMP DOWN - MULTIPLE BY CONSTANT

All ballistic tables are based on standard atmospheric conditions (SAC). There are several drag curves used in ballistics. The Sierra reloading manual lists and describes all of the different drag curves. The G1 drag curve works quite well in all of the situations that I have used it. This includes engagements against hard targets to a range of 2,330 meters at Fort Bragg. The G1 curve works well with bullet designs in the military and most bullets commonly used in reloading for competition and special operations. The SAC are as follows:

- Air temperature 59 degrees F
- Barometric pressure at sea level 29.53 in. Hg
- 0 feet altitude above sea level
- Ammunition temperature 70 degrees F
- The G1 drag function.

The following is a breakdown of each of the columns and their uses. You must understand how each of these columns are read and integrated into the formulas. It is helpful to have the Calculation Forms

(calceforms) handy and practice using them as you go through the process. They are printed at the end of this chapter

Column 1. ELEV. MOA: You remember from Chapter 5 that a MOA is an angular measurement equivalent to roughly one inch at 100 yards. This column represents the actual MOA required for the bore to be elevated above the line of sight for the round to strike at the desired point of aim. On the rifle scopes with BDCs we have numbers representing the range in hundreds of meters. The BDC dial calibrates the centered reticle so that the bore of the rifle can be quickly elevated the precise MOA needed to hit the point of aim at the ranges indicated. For example, 5 on the scope is actually a setting of 13.75 MOA. These values have a real use when using rifles with the target turret knobs that require an indexing in true MOA. A good example is the Leupold & Stevens M1A scope. In the military this scope comes on many rifles. These include the U.S. Navy M-91, U.S. Special Forces M-25 (not the SR-25) and some .50-caliber sniper rifles. These scopes have no bullet drop compensator and you must index the true MOA values from these tables on those scopes. If you do not remember this procedure, refer back to the chapter on Sight Adjustment and Zero of the Heavy Rifle.

RANGE	ELEV.
	MOA
100M	2.25
200M	4.75
300M	7.50
400M	10.50
500M	13.75
600M	17.50
700M	21.25
800M	25.50
900M	30.50
1000M	36.75

Column 2. SUPER ELEV.-MILS. The section of the table that contains data on superelevation – MILS is honestly of little use to the sniper weapons system shooter. It is intended for those rare scenarios where a sniper may have a .50-caliber machine gun and any type of ammunition. He can access this data and dial in his machine gun to the range. There are many cases of the M-2 being used as a sniper platform. With the traverse and elevation device installed on the machine gun and the tripod, a sniper can dial in his gun faster and with greater accuracy. The “Art of the Machine Gun” is a lost art in the U.S. military. The Ranger Battalions come the closest to the art. It is strong within the British Army.

RANGE	SUPER
	ELEV.-MILS
100M	0.65
200M	1.40
300M	2.20
400M	3.10
500M	4.10
600M	5.20
700M	6.30
800M	7.60
900M	9.00
1000M	10.90

Column 6. ELEVATIONS X 100. This column is a list of sight setting changes in MOA required to go from one range to the next range. It is a fast reference system and works well with the M1A scope or when interpolating values. For example, if you are at 600 meters you would have 17.50 MOA on the scope. To change to 700 meters, you go to the 700-meter range and go across to the ELEV X 100 Column and read the value. (In this case it is 4.25.) You then dial 4.25 additional MOA to the sight setting. This precludes having to do any subtracting or adding values in Column 1.

RANGE	ELEV
	X 100M
100M	2.25
200M	2.50
300M	2.75
400M	3.00
500M	3.25
600M	3.75
700M	4.25
800M	4.25
900M	5.00
1000M	6.25

Column 4. Temperature Correction Factors. (Temperature Constant) This is a constant that corrects your elevation setting for temperatures above or below the standard of 59 degrees F. You will multiply this constant against your true range when the air temperature is below 59 degrees and divide when the air temperature

RANGE	BAROMETRIC	TEMPERATURE
	PRESSURE	CONSTANT
	CONSTANT	
100M	1.00000	1.00000
200M	1.00000	1.00000
300M	1.00000	1.00000
400M	1.00000	1.00000
500M	1.00000	1.00550
600M	1.01026	1.00593
700M	1.01214	1.00638
800M	1.01482	1.00761
900M	1.01715	1.00910
1000M	1.01914	1.01059

is above 59 degrees. This correction is done after correcting for barometric pressure. The results will give you an elevation setting corrected for air temperature.

Column 5. Barometric Correction Factors (Barometric Pressure Constant) This is a constant that will correct your elevation setting for barometric pressure. The details are covered later in the chapter, but now remember that you will multiply this constant against your true range setting when the BP is higher than 29.53 and divide when the BP is lower than 29.53.

Column 7. Standard Conditions. The constants in Column 7 are corrections for elevation settings that are based on international standards of barometric pressures and temperatures for elevations above sea level. Since you almost always go up in elevation from sea level, you will divide these constants against the elevation setting to obtain the correction. This table is an emergency-use measure. If you have a map with elevations on it but do not have a barometer or thermometer, you can use Column 7 to estimate your changes due to air pressure and temperature. This is covered in greater detail later in the chapter.

RANGE	STANDARD CONDITIONS
100M	1.00000
200M	1.00000
300M	1.00000
400M	1.00000
500M	1.00000
600M	1.00855
700M	1.01043
800M	1.01236
900M	1.01514
1000M	1.01661

The next sets of tables are known as the “Secondary Function” tables. The secondary firing tables have additional data that is not linked directly to elevation settings for the sight system used. These additional data have a tremendous use in mission planning as well as mission execution. They also serve as a sanity check when a shooter may be getting ready to shoot a target at 600 meters that is a radical mover. (This means the target may not sit still long enough to be predictably struck by a round that doesn’t arrive for 1.0 seconds after being fired.)

BALLISTIC DATA MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL. AMMUNITION SECONDARY FUNCTIONS

RANGE	TIME OF FLIGHT	FALL ANGLE	DRIFT (IN.)	DRIFT (MOA)	MAXIMUM INCHES	ORDINATE FEET
100M	0.11901	.03901	.039	0.00	.65637	.05470
200M	0.24552	.08582	.123	0.00	2.65990	.22166
300M	0.38126	.14177	.295	0.00	6.85051	.57088
400M	0.52454	.20697	.564	0.00	12.99890	1.08324
500M	0.67903	.28356	.946	0.25	21.84928	1.82077
600M	0.84450	.37843	1.48	0.25	34.15119	2.84593
700M	1.02171	.48120	2.16	0.25	49.47793	4.12316
800M	1.20845	.60344	3.04	0.25	69.37816	5.78151
900M	1.43374	.77114	4.25	0.50	80.58375	6.71531
1,000M	1.65911	.97636	5.87	0.50	132.2502	11.02085
1100M	1.90095	1.1911	7.73	0.50	173.6013	14.46678
1200M	2.14396	1.4251	9.95	0.75	222.0612	18.50510
1300M	2.44381	1.7612	13.07	0.75	290.3273	24.19394
1400M	2.76441	2.1492	16.93	1.00	375.6156	31.30130
1500M	3.09585	2.5829	21.53	1.25	480.1845	40.01538
1600M	3.43806	2.9931	26.47	1.50	593.1158	49.42632
1700M	3.36584	3.4052	31.87	1.75	717.8009	59.81674
1800M	3.94627	3.8027	37.58	1.75	850.3885	70.86571
1900M	4.39449	4.2163	43.89	2.00	997.5054	83.12546
2000M	4.72368	4.6552	50.93	2.25	1162.200	96.85003

DETERMINING AND CORRECTING FOR METEOROLOGICAL AND ENVIRONMENTAL CONDITIONS

RANGE	TIME OF FLIGHT	FALL ANGLE	DRIFT (IN.)	DRIFT (MOA)	MAXIMUM INCHES	ORDINATE FEET
2100M	5.05734	5.0994	58.44	2.50	1346.373	112.19771
2200M	5.40024	5.5701	66.87	2.75	1533.807	127.81728
2300M	5.74486	6.0461	75.81	3.00	1745.580	145.46502
2400M	6.10018	6.5504	85.63	3.25	1978.608	164.88401
2500M	6.46895	7.0916	96.49	3.50	2230.990	185.91587

Column 1. Flight Time. This column gives the time of flight required for a bullet to transit the distance to the target indicated. This is the primary data used to determine the “accessibility” of a target that needs to be engaged. If you are shooting a target at 600 meters that does not sit still for more than a half a second at a time (most field commanders) he may be very difficult to put down with a killing shot.

Column 2. Fall Angle. This is the downward angle the bullet’s trajectory is following as it impacts a target. This is used to calculate danger space dimensions. It has little other use.

Columns 3 and 4. Spin Drift in Inches and MOA. This column gives you the amount of lateral drift experienced by the listed .50-caliber bullet as fired from a right hand twist barrel. This is calculated on a barrel with a twist of 1:14 at the listed muzzle velocities for each of the rounds of ammunition listed. The bullet drifts to the right due to the right hand twist.

Columns 5 and 6. Max. Ord. Inches and Max. Ord. Feet. The data in this column gives the height of the bullet above the line of sight for the ranges indicated. This is another sanity check for the shooter in the field. If you are shooting in a wooded area or an area where there are overhead obstructions to a bullet’s line of flight you need to know the Max. Ord. figure for your range. For example, a shot at 500 meters requires 2.5 feet of overhead clearance at the range where the Max. Ord. occurs at around 300 meters.

RANGE	FALL ANGLE	FLIGHT TIME
100M	.03901	.11901
200M	.08582	.24552
300M	.14177	.38126
400M	.20697	.52454
500M	.28356	.67903
600M	.37843	.84550
700M	.48120	1.02171
800M	.60344	1.02845
900M	.77114	1.43374
1000M	.97636	1.65911

RANGE	SPIN DRIFT INCHES	SPIN DRIFT MOA
1000M	5.87	0.50
1100M	7.73	0.50
1200M	9.95	0.75
1300M	13.07	0.75
1400M	16.93	1.00
1500M	21.53	1.25
1600M	26.47	1.50
1700M	31.87	1.75
1800M	37.58	1.75
1900M	43.89	2.00

RANGE	MAX ORD INCHES	MAX ORD FEET
100M	.65637	.05470
200M	2.65990	.22166
300M	6.85051	.57088
400M	12.99890	1.08324
500M	21.84928	2.84593
600M	34.15119	4.12316
700M	49.47793	5.78151
800M	69.37816	6.71531
900M	80.58375	11.02085
1000M	132.2502	14.46678

WORKING WITH THE SCIENTIFIC CALCULATOR

Before you can dive into the calculations and the use of these tables, you must understand some fundamentals about scientific calculators. Over the years I have counseled many students on which type to buy for the courses, and I have even described the type that people were required to bring in what the military calls Letters of Instruction. Now, one would think that if it were in writing and signed by the operations officer that those instructions would be followed. Not true!! I am going to suggest some calculators to use. You are going to be learning this on your own and may already be totally familiar with the type of calculator you are using. That is your choice. When I conducted a course for up to 24 students, I would have as many as 7 different types of calculators. Some were set up in degrees and some in radians. Some were accidentally put into scientific notation in the middle of the class, which forced me to stop instruction to reformat the calculator.

For the written instruction in this chapter I will be using a Hewlett Packard HP-20S. This is a calculator that I have used for years, although this is not the prime reason that I recommend it. Here are some suggested calculators and their strong points.

First choice: Hewlett-Packard HP-20S. This is my calculator of choice. It is simple, rugged, and is set up to operate in true keystroke sequence. It is not reverse Polish notation (RPN), which is a bugger to work with. The HP-20S is quite rugged. I dropped a block of steel that was about to become a scope base onto mine from about 1 1/2 feet and while it did poke quite a hole between two keys, it did not effect the operation and the calculator is still going strong. This calculator is 100-step programmable and has 10 storage cells for information. This is about right as you can store all of the elevation settings and constants for a particular firing sequence and then crunch all of the numbers. Cost: about \$30.00, available at Office Depot and Office Max or from Hewlett Packard.

Second choice: Hewlett-Packard HP-32 S. This is an RPN calculator that is capable of more memory than is the HP-20S. It has almost three times the memory cells of the HP-20S and is just as easy to access. The only difficult part is using RPN. If you are used to it, it is faster than standard keystroke entry. Cost: About \$75.00, available at the same places.

Hewlett-Packard Graphics Calculators. These are the brutes that astronauts carry. They are scientific calculators capable of graphics display, which is not really necessary for this type of work. The use of these calculators can be a nightmare. I know many students that have spent up to \$200.00 for one of these. Two or three days later, they are on a shelf and a HP-20S shows up in its place. Cost: From \$100.00 to \$300.00.

Texas Instruments Calculators. TI calculators are pretty simple and user friendly. Their main limitation is the availability of multiple memory cells. Until you get in the big graphics calculators that are RPN, they have only one memory cell. That means that you are writing down more intermediate solutions as you go. This slows down your solution time considerably. While users of the HP-20S are done by five minutes, the single memory TI users will be entering their handwritten data into the calculator for final solutions. As a backup for the battery driven HP calculators, the solar powered models make an excellent choice. For the budget-minded this is the best deal. Cost: From \$12.95 to \$45.00 depending on the model. Available anywhere calculators are sold.

Casio Calculators. These are my worst nightmare. When I ask a class, "Who has a Casio calculator?" invariably two or three students will raise their hands. I groan. Any student who has been in one of my other classes groans even louder. This is because they know the delays that are coming. Keyboard layout is important. No one at Casio, TI, or Hewlett Packard knows how I run the calculation sequence, so it's no one's fault. However, as it works out, many of the calculations have keystrokes that take place next to some very chaos-creating format changing keys. I have spent up to 20 minutes trying to figure out why a solution is different than the one I arrived at, only to find out the individual accidentally reprogrammed the calculator from degrees to radians. Another example is when in the final solution, the elevation angle is expressed in decimal format instead of degrees, minutes, and seconds. Be smart and don't use one of these.

With these rather long introductions into this chapter out of the way, we can begin. Remember when I said the goal of this chapter is to place a gun's circular error capability over the center of a target and keep it there? The target circle of capability is 2 MOA. At whatever ranges you are shooting at or thinking about in



The Hewlett-Packard HP-20S operates in true keystroke sequence.

these problems, consider how big that two-minute circle is. The circle at 1,200 yards is 24 inches. This is already larger than most soft targets. The chances that you will miss even when all the number crunching is right are quite high. The average human torso is about 20 inches across the chest. The 2-minute circle is 20 percent bigger than the target. Think of it like this: You have a 1-in-5 chance of hitting this target at 1,200 yards. If your math is not correct, your chances go down considerably. So as you read and hopefully learn, remember the two-minute circle.

When we calculate for ENV conditions, we are going to determine and correct for two phenomena.

- Slant angle from gun to target (initial calculations)
- Supersonic burnout of the bullet (final calculations)

When we determine and calculate for MET conditions we are going to measure and correct for:

- Barometric pressure (altitudes above and below sea level, as well as daily fluctuations at a fixed altitude)
- Ambient air temperature. This is the measured air temperature.

There is one internal ballistics factor that we measure and correct for. This is the temperature of the ammunition and is based on a standard of 70 degrees F.

The standard atmospheric conditions. Under international agreements on standardization, there are meteorological conditions that are used as baselines in determining many types of data. In aviation there is a certain set of standard air pressures, air temperatures, humidity, and altitudes. In shooting and ballistic research there are also a set of standard conditions that vary only slightly from the aviation standards. The ballistic standard MET conditions are:

(a) Altitude	Sea Level
(b) Barometric pressure	29.53 In. Hg or 1,000 Mb
(c) Air temperature	59 degrees F.
(d) Relative humidity	78 percent

FIRST MAJOR CORRECTION: CORRECTING FOR SLANT ANGLE TO THE TARGET

For years, many hunters have been aware of the effects of a slant angle to the target. They all pretty much know the bullet will not strike the point of aim. I asked all of the sniper students where the bullet would strike in a slant angle environment. Some of them answered low when shooting uphill and high when shooting downhill. I asked them why that was. They said, "Because of gravity?" Well, it is because of gravity, though not for the reason that they and some of you may think. I will try to explain.

The earth is a sphere. Because of its great size, we do not see the curvature of the earth. I remember the first time I saw the curve in the earth. I was doing a military freefall jump from 25,000 feet. At that altitude I noticed for the first time the curve in the earth. Gravity emanates roughly equally in all directions from the center of the earth. That is why things fall straight down when we drop them. When a bullet is fired from a rifle that is laying on flat ground it is exposed to gravity and air resistance. That is why we have to elevate the barrel for the bullet to strike the intended target. If all other conditions were never changing and we never fired uphill or downhill, we would not have to study this chapter.

When you fire uphill or downhill, the bullet will always strike high on the target. The more severe the angle, the higher it will strike. I will attempt to illustrate how this works.

DRAWING DEPICTING THE EFFECT OF SLANT ANGLE

INITIAL RANGE TO TARGET =	1600 Meters	This portion of the CALCFORM shows determining the slant angle to the target. The True Range to the target is 1600 meters.
TYPE AMMUNITION TO USE =	Mark 211, Mod-0	
SLANT RANGE CORRECTIONS		
ALTITUDE OF GUN =		The angle to the target was determined to be 22 degrees.
ALTITUDE OF TARGET =		
DIFF. OF ELEVATIONS (METERS) =		COS Angle X Trange = Slant Range to TGT
2 Methods of Slant Range Determination 1. COS Angle to TGT X True Range = Slant Range//SLANT RANGE CORR FACTOR 2. $\frac{VD \cdot \tan^{-1} \cdot \cos \cdot \text{ORIGINAL TRUE RANGE}}{HD}$ RESULT IS THE SLANT RANGE		COS of 22 deg = .92718
	22 Deg. / .92718	.92718 X 1600 = 1483.49417 Meters
CORRECTED SLANT FIRING RANGE	1483.49 Meters	Always list data to 5 decimal places.

To my surprise when I asked students this question response has been anywhere from “There is no change” (actually taught by some schools) to the above explanation, and every now and then someone gets it right. Rarely does anyone know why.

To teach this technique we will use a sniper mission scenario and talk through the procedure as we learn it for the first time. We have just been dropped by helicopter at a landing zone and have moved for several days overland to a position overlooking a road intersection. At a certain time and date, a specified target will present itself. Your mission is to engage the specified target. In the mission-planning phase, weather intelligence provided you with pressure and air temperature predictions for this operational area. Here is where we begin the process. You are in your Final Firing Position (FFP). First you have to determine the true range to the target. In the past, you knew this as simply the range. Now we have complicated matters and have designated two types of range determinations: true range and slant range. You have used several techniques to determine the true range to the target. These methods are the focus of the chapter on range determination.

First of all, true range is the initial range to the target and is found by line of sight means. It is also the amount of air that the bullet must pass through to the target. Before you determine the slant range, you must know the true range. Again, remember that true range represents the amount of *air* between the gun and the target. No matter what the final slant range is, the bullet must travel through that true range amount of air. If the original true range was 1,600 meters, but because of a 22-degree slant the slant range is now 1,483.49 meters, the bullet must still go through 1,600 meters of air. The wind will blow the bullet for 1,600 meters. The effects of barometric pressure will work on the bullet for 1,600 meters. The effects of ambient air temperature will work on the bullet for 1,600 meters. If you ignore these effects you will miss the target. To correct for this slant angle, you have several options.

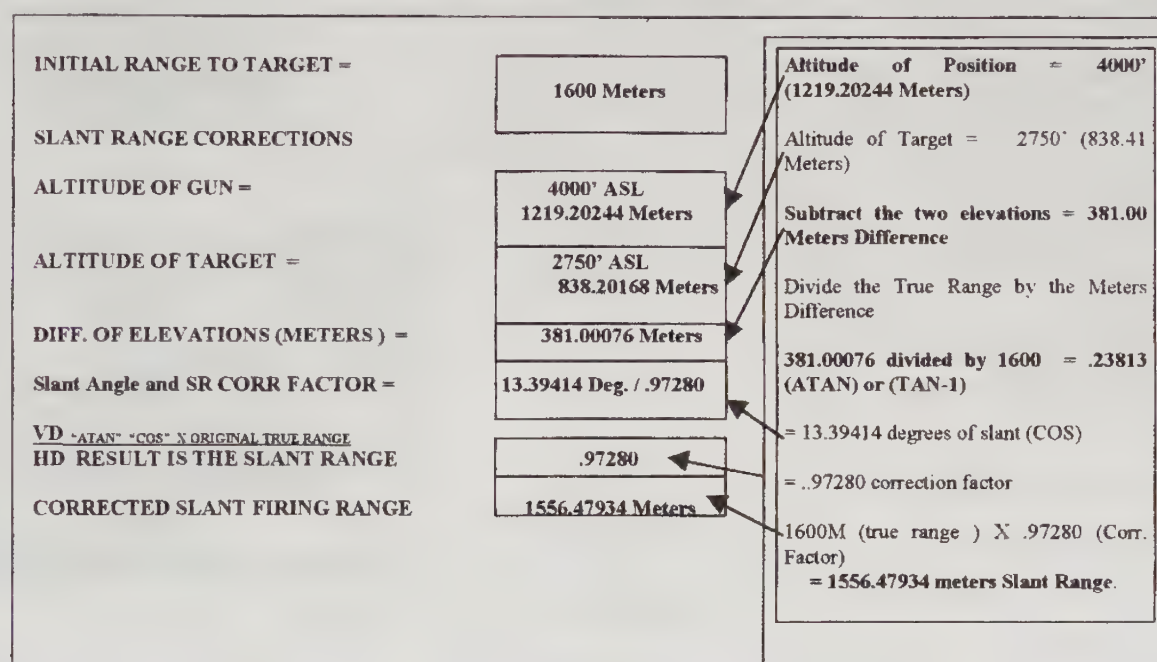
Use the calcform to record your calculations and make final shooting solutions. Here are some methods:

The protractor method. The first method to determine the slant range to the target is somewhat unsophisticated, but it works well enough for .308 shooting in real world sniper engagement ranges. In this method, the sniper team takes a protractor and hangs a string and weight from the value of 0 degrees. A straw is glued along the bottom of the protractor. This serves as a crude sight. A sighting is taken from the gun to

the target line. The observer then looks at the protractor and reads the degree of slant on the scale. With a scientific calculator the observer takes the cosine of the degrees of slant (known as the slant range correction factor) and multiplies this against the measured true range to the target. Remember that the true range is also the amount of AIR that is between the shooter and the target. The result is the new range to the target known as slant range.

The cosine key on your calculator will be identified by a key labeled COS. On some calculators, this may be a second function. On Hewlett Packards, it is not. When doing the math always work out five decimal places. Over a long string of calculations, rounding off at two decimal places will result in unfavorable errors.

GPS method. The second method of determining slant range is to use a GPS (Global Positioning System) receiver to calculate the slant range to the target. In this method the shooting team determines the true range to the target by their determined means, then uses the GPS to input the range and the magnetic azimuth to the target. The GPS will calculate the slant range for you. It will also give you the MGRS location of your target if need be for fire support or CAS missions.



EXAMPLE:

True range = 1,600 meters.
 Degrees of slope = 22 degrees
 Cosine of degrees of slope = $\text{COS } 22 = .23813$.
 Slant range correction factor - .97280
 $1,600 \text{ m} \times .97280 = 1556.47934 \text{ meters slant range}$

Map sheet method. The third method of determining slant range is by using a map sheet. This gives you a very rough but usable estimation of the degrees of slant to the target. Critical information is the contour interval of the map sheet and your ability to determine your precise location on that map sheet. If you have a GPS, use that method. In using the map, you determine the altitude of your position. Then you determine the location of your target site. If the map sheet is in feet, you must convert the data to common units of measure. In this case we will convert to meters. The true range is 1,600 meters to the target. The altitude of the sniper team is at 4,000 feet ASL. The altitude of the target is at 2,750 feet ASL.

Additional Methods. For military personnel there are other options on how to find the altitude of the target. In mission planning, imagery available from national sources frequently contains the latitude, longitude, and altitude above sea level of the target area. With this knowledge of the altitude of the target, teams can calculate possible shooting angles during mission planning.

During the HTI course that SOTIC 1st SFGA ran in Yakima, WA, in 1996, we used theodolites to determine the range to the target. Details on this method are found in Chapter 7. A spin-off of using this device is that it reads vertical angles to a very accurate level. While you are determining the angular deflection for the size of the target, you also obtain the up or down slant angle to the target.

Refer to the example on page 161. You are dealing with two different ranges. The first range is true range (Trange), the actual amount of air between the gun and the target. This is 1,600 meters. After correcting for the slant angle to the target you have a "gravity range" of 1,556.47943 meters. These two figures are very important. The greater the difference between these two figures the greater the error that results from mixing the two numbers up. Remember that from this point forward all corrections for barometric pressure and air temperature, windage, and anything else are taken from the true range figure. It makes no difference if you're shooting uphill or downhill.

Indexing the true range and slant range elevation settings. Remember that there are two ranges that you must be concerned with. Now for a quick review.

INITIAL RANGE TO TARGET =	1600 Meters
TYPE AMMUNITION TO USE =	Mark 211, Mod-0
SLANT RANGE CORRECTIONS	
ALTITUDE OF GUN =	1219.20244 Meters
ALTITUDE OF TARGET =	838.20168 Meters
DIFF. OF ELEVATIONS (METERS) =	381.00076 Meters
2 Methods of Slant Range Determination	
1. $\text{COS Angle to TGT} \times \text{True Range} = \text{Slant Range} // \text{SLANT RANGE CORR FACTOR}$	
2. $\text{VD} - \text{ALAN} - \text{"COS" X ORIGINAL TRUE RANGE}$	
HD RESULT IS THE SLANT RANGE	13.39414 / .97280
CORRECTED SLANT FIRING RANGE	1556.47934 Meters

INITIAL ELEVATION (MOA) TRUE RANGE
ALL MET. CORRECTIONS ARE BASED ON THIS RANGE

ELEVATION SETTING FOR SLANT RANGE
INDEX THIS SETTING ON THE SCOPE (MOA)



Sokkia TM1A mechanical theodolite.



SOF sniper calculating the slant angles.



Obtaining the slant angle with a T-16 mechanical theodolite with 6-inch capability.

- True range is the actual distance from the gun to the target. This represents the amount of *air* between the gun and the target. Both corrections for MET effects are based on the true range. Again this is because you are correcting for air conditions and true range represents how much air the bullet has to travel through. In the example: 1,600 meters.
- Slant range will always be a smaller number. When there is no slant angle, slant range doesn't exist. The effects of gravity when concerning slant range will always be less because of the relativity of the trajectory to the emanations of gravity from the earth. This number is the first elevation setting that is indexed on the scope. After that, it pretty much doesn't get used again. In this example: 1556.47934 meters.

Obviously, many shooting environments do not have the effects of slant range. When shooting on a known distance range, it is highly unlikely that there will be a slant angle involved. In this case, you are only concerned with the true range data. Once you have determined the true range and if necessary the slant range, you will need to consult your firing table to determine the correct elevation setting to place in the calcfom to determine the corrections for MET and ENV conditions.

BALLISTIC DATA MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL.AMMUNITION

RANGE	SUPER ELEV-MOA	SUPER ELEV-MILS	SUPER-ELEV. PER 100 METERS	TEMP. CORRECTION FACTORS	BAROMETRIC CORRECTION FACTORS	ALTITUDE CORRECTION FACTORS	REMAINING VELOCITY
1300M	57.75	17.10	8.50	1.01598	1.02781	1.02373	1153 FPS
1400M	67.50	20.00	9.75	1.01782	1.03046	1.02660	1080 FPS
1500M	78.50	23.25	11.00	1.01914	1.03299	1.02911	1024 FPS
1600M	89.25	26.40	10.75	1.02035	1.03510	1.03145	986 FPS

In the first example above, we have a true range of 1,600 meters. Refer to the firing table for Mark 211, Mod-0 ammunition and go down to the range of 1600M. Trace to the right until you are in the SUPER ELEV MOA column. This value is 89.25 MOA. Refer to the calcfoms that you have next to you. The very next section down from calculating true and slant range is the portion of the calcfom that requires the data for INITIAL ELEVATION (MOA) TRUE RANGE and ELEVATION SETTING FOR SLANT RANGE. This is recorded in the box marked for true range. At this point there are two hard and fast rules for using these two elevation settings. Confusion of these rules will certainly lead to miscalculations and misses:

1. True range is a number that is used for calculations only. Its value in MOA is not placed on the rifle scope unless there is no slant angle to the targets.

INITIAL ELEVATION (MOA) TRUE RANGE ALL MET. CORRECTIONS ARE BASED ON THIS RANGE	89.25 MOA	True Range Elevation setting from Primary Function Table.
ELEVATION SETTING FOR SLANT RANGE INDEX THIS SETTING ON THE SCOPE (MOA)		

- Slant range is the value for elevations obtained where there is a slant angle to the target. This data is entered on the calcforn. This setting is then placed on the elevation dial of the rifle scope.

Take special note of Rule 1. More sniper students have made mistakes concerning these two rules than any math problems that they execute. True range never goes on the scope unless there is no slant range. Then the number for true range and slant range will be the same. Always fill in every box on the calcforn. This will help make errors more detectable. Remember that in a classroom, or when working with problems for which there are published solutions, it is easy to check your work. When you are alone with your sniper partner and the two of you have differing solutions, it will be difficult to tell who is correct and who is not.

OK, that one was easy. All we had to do was consult the firing table and determine the elevation setting for 600 meters. There was no slant range involved. In this next problem, we have both true range and slant range. Here another mathematical process is required. It is called interpolation. Interpolation is the process of finding an unknown number between two known numbers. The tables provide the values for 1,500 and 1,600 meters. We need the value for 1,556.47935 meters. Follow the example below and work the problem with your own calcforn cards.

The second elevation setting requirement is for slant range. Using the above example for interpolation we have already determined the slant range elevation setting. Remember that slant range solutions will always be a smaller number. If your slant range figure is larger than the true range figure, you did it incorrectly.

In this sample problem the slant range to target is 1,556.47934 meters. After using the above method of interpolation, the sniper determines the slant range elevation setting to be 84.57153 MOA. This data is entered on the calcforn as depicted below. Again note that the true range number is LARGER than the slant range number. This will always be the case!!!

Again, it is important to note the use of the two elevation settings—one for true range and one for slant

EXAMPLE: What is the come-up for 1556.47934 meters for Mark 211, Mod-0 .50 caliber ammunition?

- Start with the known elevation settings for the true range (1600 meters. And the setting for the range 100 meters nearer than that for 1600 meters (in this case the setting for 1500 meters).

Come up for 1600 meters = 89.25 MOA

Come up for 1500 meters = 78.50 MOA

- First, subtract the smaller value from the larger value

$$\begin{array}{r} 89.25 \text{ MOA} \\ -78.50 \text{ MOA} \\ \hline \end{array}$$

- The result of this is the number of minutes from 1500 to 1600 meters. 10.75 MOA

We are trying to find the value of the MOA come-up for 1556.47934 meters.

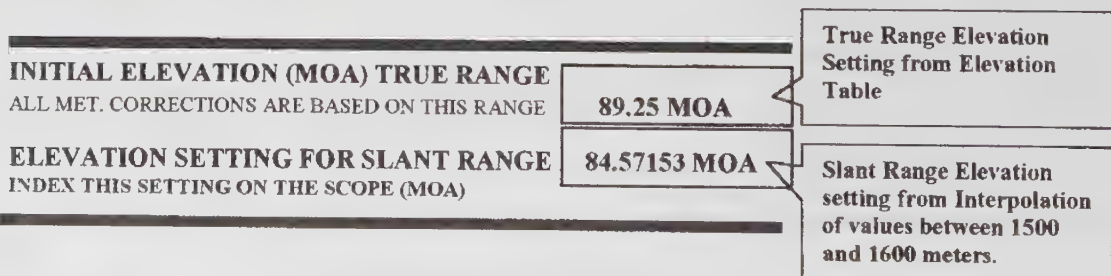
- Drop the digit in the "hundreds" ("15"56.47934) position, (leaving 56.47934) and divide this number by 100. (=5647934) and multiply X the number of minutes between 1500 and 1600 meters. Put a decimal point in front of the number as this is decimal value of the distance you are trying to this is the find.

$$\begin{array}{r} 10.75 \text{ MOA} \\ \times 5647934 \\ \hline 6.07153 \text{ MOA} \end{array}$$

- At this point, the result (6.07153) is added to the "LOW" MOA value.

$$\begin{array}{r} 78.50 \text{ MOA} \\ +6.07153 \\ \hline 84.57153 \end{array}$$

- Result is the total MOA elevation: MOA



range. True range elevation settings are for calculation purposes only. They do not go on the scope. If there is a slant range setting determined, this is placed on the rifle scope and left alone. The only time a true range setting goes on the scope is when there is no slant range. I do not mean to be repetitive, I am merely trying to imprint these rules in the mind.

Remember that true range represents the amount of air between the gun and the target. This is the range on which all corrections for barometric pressure and air temperature are based. The setting for slant range is on the rifle scope. All corrections based on ENV and MET conditions are done by taking MOA off of the scope setting or adding MOA to the value on the scope setting.

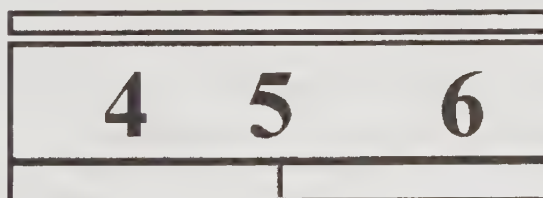
Let's review what we have done so far.

1. We determine the range to the target using any range finding methods we can. This range is called the true range. Enter this on the calcfom.
2. We determine the slant angle to the target (if any) in degrees. We take the cosine of the degrees of slant and multiply this value against the true range. This gives us the slant range. This number will always be smaller than the value of the true range. Enter this on the calcfom.
3. We consult the firing tables and obtain the true range sight setting in MOA. This may require interpolation. That true range sight setting is entered on the calcfom in its required slot.
4. We again consult the firing tables and obtain the sight setting for the slant range. Again, this may require interpolation. The slant range sight setting will be entered on the calcfom. The shooter then places this value on the scope of the rifle.
5. Remember: Unless true range and slant range are the same, true range is a basis for mathematical corrections and the slant range sight setting goes on the telescopic sight. As you obtain corrections against the true range, you place these corrections against the value on the scope.

At this point, it is probably a good idea to review some information about the two primary optical sights used on Sniper Weapons Systems (SWS) in the United States and in many countries of the world. If they are not one of these two optics, they are of the same principle and the methods involved in these books can be easily applied.

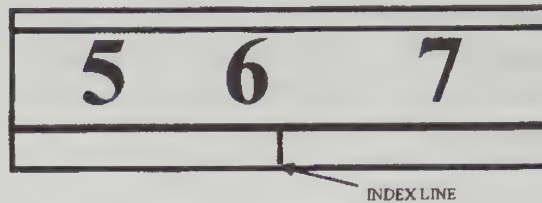
LEUPOLD & STEVENS MARK IV, M3A

A BDC is used on the M3A scope. The BDC on the M3A has ranges indicators from 1 to 10. On the M-24 SWS and other weapons using the M118SB ammunition The ring is also mark identified with the designation "7.62mm M118 Special Ball." There are other rings that are available for other types of ammunition. Numbers 1 through 10 correspond to the ranges in hundreds of meters (100 through 1,000 meters).



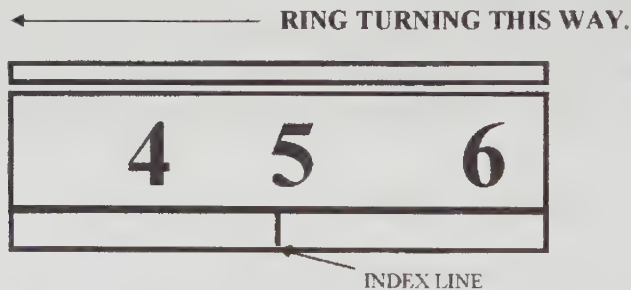
The above drawing is a depiction of the BDC ring on a Leupold & Stevens Mark IV, M3A scope. The value that is depicted is the setting for 500 meters. I am going to explain something that may be a little difficult to follow. If you look at the Primary Functions Table for M118 SB you see that the number 5 represents 18.25 MOA. That part is easy. Now look across to the column that is titled ELEV. X 100. You will

see that the number of minutes required to go from 500 meters to 600 meters is 5.25 MOA. If you were to take an M3A scope and line up the number “5” as above and then dial “up” 5 MOA your dial would look something like this:



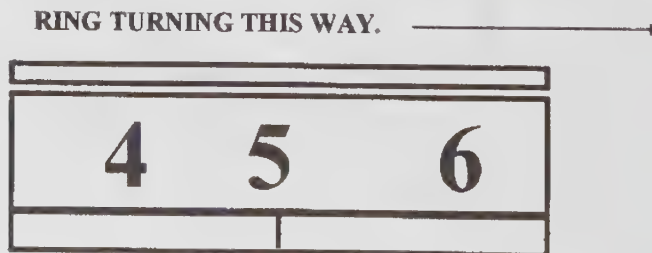
You may ask yourself, why did the index mark line up 1 MOA to the right of the number 6? This is a good question. I will try to explain why and why it is important. Because of the mechanism and the way the ring is “cut,” there is a 1 MOA excess between the number values above the number 4. If you took the number of MOA that are required to come up from one range to the next off of the table, you would end up 1 MOA past the digit on the ring. Now the original intent of this ring is to simply dial in the range to the target and you will get an impact where you are aiming. This is only possible under standard atmospheric conditions and on flat ground. Now you are learning a method of correcting for MET and ENV conditions. The technical reason for doing what we are going to do, I have addressed. Details would take too much time and space here. Trust me, I know what I am talking about. Here are two more rules to use when indexing corrections on the M3A scope.

1. When counting MOA “UP,” start with the index line on the scope 1 MOA down from the center of the digit on the ring. It looks like this:



SET INDEX MARK AS ABOVE FOR ADDING MOA TO THE VALUE OF “5”.

2. When counting MOA “DOWN,” start with the Index Line on the scope dead center under the value of the digit. It looks like this:



SET INDEX MARK AS ABOVE FOR REMOVING MOA FROM THE VALUE OF “5”.

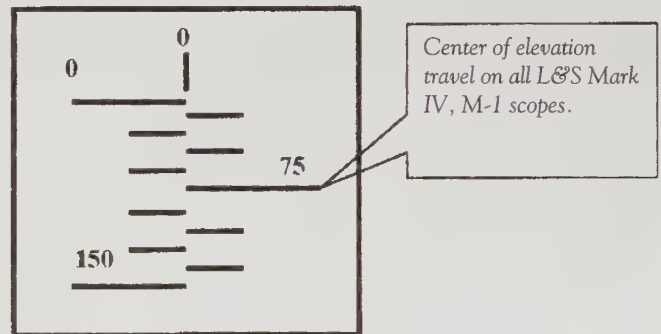
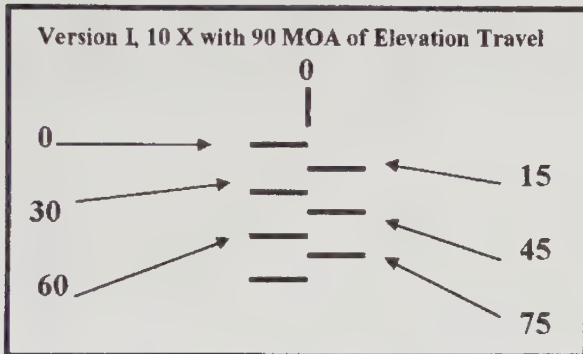
LEUPOLD & STEVENS MARK IV, M1A

The M1A telescopic sight is very different than the M3A scope. Remember from Chapter 2 that this scope is quite similar to the Redfield Palma sights or any other match 1/4 MOA sights in use. Virtually every gun shop that builds Sniper Weapons System uses this scope. It is used on the .308 class weapons, although it is my personal opinion that the M3A is better suited to military class .308. Current applications in the U.S. Special Operations Forces community are on the M700 .300 Winchester Magnum (M-91) built by NSWC, Crane, selected .50-caliber SWS, M-91 in 7.62mm built for U.S. Navy SEAL teams as built by NSWC, Crane.



The elevation knob on the M1A scope is graduated in 1/4 MOA. It is not

to be considered a BDC or a ballistic cam. If you do not remember the operations of this scope, refer to Chapter 2. If you don't have an M1A or don't need to know about it, read on and skip this part. Below is a sketch of the knob face of the M1A.



There are no external numbers on the knob of the M1A 10X scope.
The numbers in the drawing are there only to indicate the value of each hash line.
Version II, 16 and 20 Power, with 150 MOA of Elevation Travel

On scopes of this design (there are many of them) you simply index the initial elevation setting. That would be the slant range elevation setting if there is a slant angle involved. If there is no slant angle, then you index the true range elevation setting. You simply dial UP if you are adding MOA and DOWN if you are subtracting MOA.

We have learned how these different elevation settings are placed on the scope. If you still are fuzzy about how to place corrections on the different scopes, don't worry. We'll go through this information several times as we work these formulas and problems. The only way to get good at it is to do the problems many times and become familiar and comfortable with the calculator and optical sights.

Meteorological conditions are conditions in the atmosphere that affect the flight of the bullet on its trajectory. There are only two MET condition corrections that we can determine, calculate, and correct for in a field environment. These are barometric pressure and air temperature.



A hard-target operator crunches the numbers.

Determining and Correcting for Barometric Pressure

Barometric pressure is a measurement of atmospheric pressure. Atmospheric pressure is nothing more than a unit of pressure equal to the pressure of air at sea level, or about 14.7 pounds per square inch. Remember that standard atmospheric air pressure is 29.53 In. Hg. A sniper team has four primary means of determining barometric pressure.

1. Hand Held Barometers.

These instruments are available within the organic Special Forces Group. They are assigned to the Air Force Weather Detachment. They are part of a field weather kit that has all of the

instruments a sniper team needs. This digital device gives barometric pressure in 4 different units of measure, air temperature, and humidity, and can be programmed to give a historical record of all of these measures over a period of time.

2. Air Force Weather Predictions and Plots.

These can be extremely useful but they have limitations. They are based on the nearest weather recording station. This is usually an airport. Keep in mind that it probably would have to be the nearest friendly airport. This can be many miles away from the target area. Even if the target is close, there may be radical geographical differences that would result in terribly inaccurate weather predictions in your target area. The U.S.A.F. weather detachment can provide vast amounts of data that helps sniper team mission planning and execution.

3. Data Based on Standard Conditions for Altitudes ASL.

This may seem like the least desirable method. There is no comparison to using hand-held instruments. It may be more accurate than method 2, especially when the nearest weather recording station is located miles from the target area. In this method you take your elevation from map data. Once you have your elevation, you go to the table that lists the standard barometric pressures and temperatures for altitudes as agreed upon by international standards agreements.

4. Casio Triple Sensor Watch.

This watch is an exceptionally accurate instrument for measuring MET conditions. The watch can track and measure temperature in both celsius and fahrenheit. It can measure barometric pressure in millibars and inches of mercury. It measures the altitude above sea level. As an added feature it has a digital compass.

**BAROMETRIC PRESSURE = 24.68 IN. HG
STANDARD AIR TEMPERATURE = 37.6**

ALTITUDE	PRESSURE In. Hg	PRESSURE Mb	ASL' TEMP.
1,000 ft.	28.67	971.25	55.4
2,000 ft.	27.84	943.14	51.9
3,000 ft.	27.02	915.36	48.3
4,000 ft.	26.22	888.26	44.7
5,000 ft.	25.44	861.83	41.2
6,000 ft.	24.68	836.08	37.6
7,000 ft.	23.94	811.02	34.0
8,000 ft.	23.21	786.29	30.5

Here is an example of how interpolation works: A sniper team is at their final firing position. Their instruments for measuring barometric pressure and air temperature are damaged and of no use. With a map check and GPS fix, they determine their altitude above sea level to be 6,000 feet ASL.

This is a table of standard barometric pressures and air temperatures for altitudes above sea level. For altitudes between 1,000-foot bands, the shooter will have to interpolate the value.

By checking their data book, they determine the following conditions exist. The barometric pressure listed will have to be used. There is no way to make an educated guess about what the BP might be. The temperature is another matter. Although it is cold enough to see their breath and they are slightly below the snow line, there is no ice forming and they agree with the table suggestion of 37.6 degrees F. It is an educated conclusion. This method will usually get the sniper team within 2-3 MOA of true elevation settings even under extreme conditions.

In this first problem, we will use an even number range to determine the barometric pressure correction. This is a simple one and is not related to the problem that we have been working up to this point. Here is the data available:

**RANGE TO TARGET: 1,600 METERS
BAROMETRIC PRESSURE CONSTANT TO USE: 1.03510**

**BALLISTIC DATA
MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL.AMMUNITION**

RANGE	SUPER ELEV-MOA	SUPER ELEV-MILS	SUPER-ELEV. PER 100 METERS	TEMP. CORRECTION FACTORS	BAROMETRIC CORRECTION FACTORS	ALTITUDE CORRECTION FACTORS	REMAINING VELOCITY
1,400M	67.50	20.00	9.75	1.01782	1.03046	1.02660	1080 FPS
1,500M	78.50	23.25	11.00	1.01914	1.03299	1.02911	1024 FPS
1,600M	89.25	26.40	10.75	1.02035	1.03510	1.03145	986 FPS

In the above situation, all we did was go to the range in meters to the target. Trace across until you get to the column that is titled Barometric Correction Factors. You then record that constant.

INITIAL ELEVATION (MOA) TRUE RANGE		89.25 MOA
ALL MET. CORRECTIONS ARE BASED ON THIS RANGE		
ELEVATION SETTING FOR SLANT RANGE		84.57153 MOA
INDEX THIS SETTING ON THE SCOPE (MOA)		
CORRECTIONS FOR BAROMETRIC PRESSURE		
BP UP - MULTIPLY /// BP DOWN - DIVIDE // STANDARD BP = 29.53 In. Hg.		
MEASURED BAROMETRIC PRESSURE OR USE THE STANDARD FOR THE ALTITUDE = YOU ARE AT, IF YOU HAVE NO BAROMETER	→	24.68 In. Hg.
BP CORRECTION FACTOR FROM TABLES =	→	1.03510
SUBTRACT THE MEASURED BP FROM 29.53 AND ENTER THIS NUMBER HERE.		4.85
MOA CORRECTION TO PUT ON SIGHT		
+ OR - MOA TO APPLY TO THE ELEVATION SETTING		NEW ELEVATION SETTING BASED ON BP
- 13.75051 MOA		75.49949 MOA

Above is an example of the portion of the calcfom that deals with corrections for barometric pressure. Again follow on your calcfom and pencil in data to get used to the process.

The true range is 1,600 meters. You use the constant for true range NOT slant range. If the true range is an in-between range (for example 545 meters), use your interpolation card to determine the constant value for this range. Below is the BP data gained from the standard conditions table. You need to become intimately familiar with interpolation techniques. In this case 1,600 meters is the true range. There is no need to interpolate the constant values.

BP UP - MULTIPLY, BP DOWN - DIVIDE

This means that when the barometric pressure is up, you will multiply the true range elevation setting against the BP correction factor. Consequently, when the BP is down, you will divide the true range elevation setting by the BP correction factor.

You will divide or multiply the correction factor one time for each inch of pressure change for barometric pressure.

CALCULATION STEPS FOR THE ABOVE EXAMPLE

1. The shooter must determine the measured barometric pressure to plug into the calculation form
2. The next piece of data is the actual correction constant from the Mark 211, Mod-0 tables. In this situation this constant is 1.03510 for a range of 1,600 meters.
3. The third piece of information requested is a factor known as the "Multiplication Factor Value." This is obtained by subtracting the measured barometric pressure from the standard BP of 29.53 In. Hg. Note that the standard BP is listed in the calcfom for a reminder. In this case the result is 4.85. This is entered in the block indicated.

$$29.53 - 24.68 = 4.85 \text{ (Multiplying Correction Factor Value)}$$

SUBTRACT THE MEASURED BP FROM 29.53 AND
ENTER THIS NUMBER HERE. _____

4.85

4. Next we run the calculator sequence. At this point locate the “yx” key on your calculator, it may be a second function so look carefully. Remember that you use the elevation setting for true range because we are correcting for the amount of air between the gun and the target. This MOA value is 89.25 MOA. Read the rules of calculation on the form.
5. You may note that it would be difficult to multiple or divide the constant against the true range setting by a factor of 4.85 times. The “yx” key is used to multiply or divide numbers against each other including a decimal value. Instead of having to multiply or divide high and then low, then interpolating the value of .85, using the “yx” key allows the operator to bypass the pain-in-the-butt interpolation process. This is why we use the “yx” key.

ENTER “89.25” on your calculator. In this case the pressure is down so we divide.

- **Hit the “divide” key.**
- **ENTER “1.03510”**
- **Locate and hit the “yx” key**
- **ENTER “4.85”** The Multiplication Factor Value, taken from subtracting the measured Barometric Pressure from the Standard Barometric Pressure.
-
- **Hit the “=” Key.**
- **Result = “75.49949” MOA**

I would not recommend indexing any corrections on the scope until you are completed with all calculations. In a tactical situation, you may be in a big hurry and of course you can index these corrections as you obtain them. If you have to shoot, at least you will have that circle closer to the center of the target than you would have if you did not try to obtain the corrections. If you have the time, wait until the end and place all corrections on the scope at one time. If you do the corrections as you obtain them, you will have to round off subsolutions as you calculate them. In the end this could end up with as much as a 1 MOA error due to rounding off. Scopes and sights with 1/4 MOA capability will not have as much error as do scopes and sights that are only 1 MOA capable.

None of this information is any good unless you can index the data on an iron or optical sight. Because of the many types of sights that are available, listing all of the methods for each sight would take forever. In the above example of the BP correction, the final sight change is -13.75051 MOA. This figure cannot be entered on any sight. This figure must be rounded up or down to the nearest available MOA adjustment.

Below are the different methods that apply for each of the three types of sight systems used commonly on sniper weapons systems in the United States.

Initial scope setting is put on the sight. This figure is rounded off to 84.50 MOA.

A) TRUE RANGE
 SED ON THIS RANGE **89.25 MOA**
 84.57153 MOA

COPE (MOA)

This is the number of MOA to "takeoff" of the elevation setting on the scope. This updates your sight to the most current MET conditions available. If the shooter had to shoot right now, he would be that much more correct.

BAROMETRIC PRESSURE
 // STANDARD BP = 29.53 In. Hg.
 24.68 In. Hg.
 1.03510
 4.85
 NEW ELEVATION SETTING BASED ON BP
 75.49949 MOA

MOA TO APPLY TO THE ELEVATION SETTING
 - 13.75051 MOA

ACTION TO PUT ON SIGHT

This is the new elevation setting after correcting for barometric pressure. The figure is rounded off to 75.50 MOA to apply.)

1. For the 1/4 MOA competition rear sight, you would round off -1.68927 to the nearest 1/4 MOA. This would be -1.75 MOA or -7 clicks of elevation on the 1/4 MOA sight.
2. For the Leupold & Stevens Mark IV, M3A or other scopes with elevation clicks that equal 1 MOA, round this figure to -2 MOA.
3. For the Leupold & Stevens Mark IV, M1A or other 1/4 MOA scopes, round off -1.64546 to the nearest 1/4 MOA. This would be -1.75 MOA or -7 clicks of elevation on the 1/4 MOA scope.

Below is a portion of the second page of the calform. As data is obtained from other solutions, it must be entered on this part of the calform. This is the sanity check for the process.

TRUE RANGE = **89.25** **SLANT RANGE** **84.50**

CALCULATE ALL CORRECTIONS FROM THE RANGE ELEVATION. CALCULATED.

RE-CALCULATE FOR VELOCITY CHANGES DUE TO AMMO TEMPERATURE

APPLY ALL CORRECTIONS SLANT RANGE AFTER

+/- FOR BP CORR. = - 13.75

+/- FOR TEMP. =

When you obtain the True Range and Slant Range Elevation Setting on Page 1, enter this data on the Page 2 also. Round off to a usable figure. 84.57153 to 84.50 MOA.

As you obtain corrections for Barometric Pressure and Air Temperature enter this data on Page 2.

This serves as a data-tracking card when it is time to enter all of the elevation corrections, UP or DOWN on the scope or iron sight.

Calculating the Correction for Air Temperature

Correcting the elevation setting for air temperature is the next step after barometric pressure. The procedure is the same as barometric pressure. Also as with barometric pressure, interpolation of the correction constant may be necessary.

Note: Here is a major change for personnel who have received this training in SOTIC courses. Previously you carried the elevation setting corrected for barometric pressure over to the temperature correction page. This was in error. Use the true range elevation setting to calculate the correction for temperature. In the previous method, the error was small. However, we want to eliminate all errors.

BALLISTIC DATA

MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL.AMMUNITION

RANGE	SUPER ELEV-MOA	SUPER ELEV-MILS	SUPER-ELEV. PER 100 METERS	TEMP. CORRECTION FACTORS	BAROMETRIC CORRECTION FACTORS	ALTITUDE CORRECTION FACTORS	REMAINING VELOCITY
1,400M	67.50	20.00	9.75	1.01782	1.03046	1.02660	1080 FPS
1,500M	78.50	23.25	11.00	1.01914	1.03299	1.02911	1024 FPS
1,600M	89.25	26.40	10.75	1.02035	1.03510	1.03145	986 FPS

TEMPERATURE UP - DIVIDE, TEMPERATURE DOWN - MULTIPLY

This means that when the air temperature is up, you will divide the true range elevation setting against the air temperature correction factor. Consequently, when the air temp. is down, you will multiply the true range elevation setting by the air temp. correction factor. You will divide or multiply the correction factor one time for every 10 degrees of change in the air temperature. Remember to use the “yx” key for factors involving tens and hundreds values.

1. The first piece of information the shooter plugs into the calcfom is the true range elevation setting. This goes into the first block.
2. The measured air temperature goes into the second block.
3. The next piece of data is the actual constant from the Mark 211, Mod-0 tables. In this situation the temperature constant is 1.02035 for a range of 1,600 meters.
4. The fourth piece of information requested is a factor known as the “multiplication factor value.” Note that the standard air temperature is listed in the calcfom for a reminder. When you subtract the current air temperature from the standard air temperature you must move the decimal point ONE PLACE TO THE LEFT. Subtract 59 from 100 degrees and the answer is 41.0. Move the decimal point one place to the left and the answer is 4.10. This is entered in the block indicated.
5. Next we run the calculator sequence. Locate the “yx” key on your calculator. Remember that you use the true range elevation setting. You should be using the number 89.25 MOA to initiate the corrections for air temperature. At the top of the next page is the calculator sequence.
6. The resulting answer, 82.17442, is entered into the block labeled MOA CORRECTION FACTOR (MOA). Subtract this number from the true range elevation setting. (89.25). This result is the change in the sight setting that you actually index on the scope. In this case the change is -7.07558 MOA. This data is entered in the box on the calcfom on the following page.

- ENTER "89.25" on your calculator. In this case the temperature is up so we multiply.
- Hit the "divide by" key.
- ENTER "1.02035"
- Locate and hit the "yx" key
- ENTER "4.10" The Multiplication Factor Value, taken from subtracting the measured Air Temperature from the Standard Air Temperature.
- Hit the "=" Key.
- Result = "82.17442" MOA

CORRECTIONS FOR TEMPERATURE TEMP UP - DIVIDE /// TEMP DOWN - MULTIPLY	
INSERT TRUE RANGE ELEVATION DATA SETTING. THIS IS THE "UNCORRECTED" TRUE RANGE SETTING.	89.25 MOA
STANDARD OF 59.0 DEGREES FAHRENHEIT MEASURED TEMPERATURE OR USE THE STANDARD AIR TEMPERATURE FOR THE ALTITUDE YOU ARE AT. IF OBVIOUSLY IN ERROR WITH TABLE, TAKE A GOOD GUESS.	100 DEG F.
Page 1 of the CALCFORM	
Page 2 of the CALCFORM	
TEMPERATURE CORRECTION FACTOR	1.02035
MULTIPLICATION FACTOR VALUES	4.10
+ OR - MOA TO APPLY TO THE ELEVATION SETTING - 7.07558 MOA	MINUTES OF ELEVATION 82.17442 MOA

89.25

divide by
Multiply for Temperature Down
Divide for Temperature UP

1.02035

"yx" KEY

4.10

=

82.17442 MOA

89.25

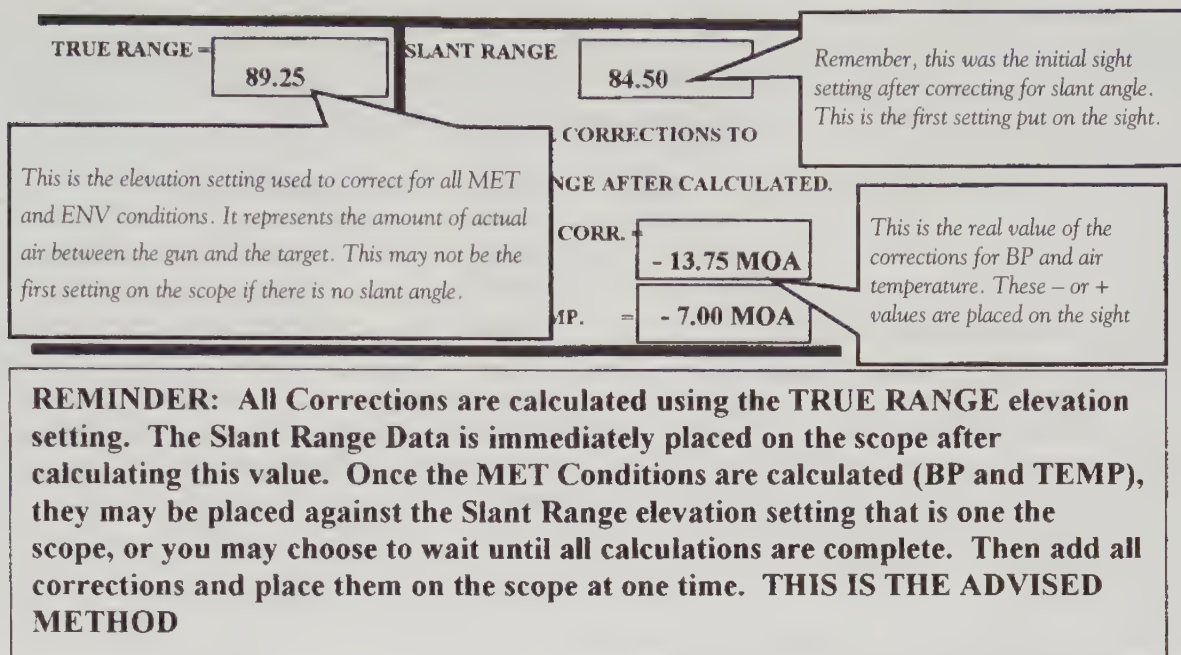
-82.17442 MOA

= 7.07558 MOA

Round up to .50 MOA in the change for the Air Temperature.

Reminder: All corrections are calculated using the true range elevation setting. The slant range data is placed on the scope immediately after calculating this value. Once the MET conditions are calculated (BP and temperature), they may be placed against the slant range elevation setting that is on the scope, or you may choose to wait until all calculations are complete. Then add all corrections and place them on the scope at one time. This is the advised method.

Again, let me remind the graduates of previous SOTIC courses, of the change. You use the TRUE RANGE ELEVATION SETTING for corrections for barometric pressure AND corrections for air temperature. This actually makes it easier. It is also much more accurate.



Calculating the Corrections to Elevation Settings for Ammunition Temperature

This is the only internal ballistics factor that we measure and correct for. You correct for the temperature of ammunition as much as possible for the following reason: The colder the powder and primer combination is, the slower the powder will burn. This causes a low muzzle velocity. The result is a lower point of impact on the target at indicated ranges.

The rule of thumb is: raise the sights to compensate for cold ammunition. The hotter the ammunition the higher the point of impact is above your point of aim.

Use the table below to obtain essential data to correct for this factor.

The correction process

There are several methods of obtaining the ammunition temperature. The first involves placing a thermometer inside the container that holds the ammunition. The U.S.A.F. weather package has the perfect thermometer for this—it is a digital device with a remote probe. Place this in the container or under the cover with your ammunition and it will give you a very accurate reading on the temp of the ammunition. You must allow enough time for the ammunition to catch up to the ambient air (air surrounding the ammunition) if you have taken it from one container to another.

AMMUNITION BURN RATE CONVERSION CHART

AMMO TEMP.	CONVERT FACTOR	STANDARD AMMUNITION TEMPERATURE OF 70 DEGREES			
		V= 2840	V=2910	V=2950	V=3950
0 Deg	-.0323	-91 fps	-94 fps	-95 fps	-127 fps
10 Deg	-.0302	-86 fps	-88 fps	-89 fps	-119 fps
20 Deg	-.0275	-78 fps	-80 fps	-81 fps	-109 fps
30 Deg	-.0241	-68 fps	-70 fps	-71 fps	-95 fps

THE COMPLETE .50-CALIBER SNIPER COURSE

AMMO TEMP.	CONVERT FACTOR	V= 2840	V=2910	V=2950	V=3950
40 Deg	-.0199	-57 fps	-58 fps	-59 fps	-70 fps
50 Deg	-.0147	-42 fps	-43 fps	-43 fps	-58 fps
60 Deg	-.0082	-23 fps	-24 fps	-24 fps	-32 fps
70 Deg	.0000	No Change	No Change	No Change	No Change
80 Deg	+.0101	+29 fps	+29 fps	+30 fps	+40 fps
90 Deg	+.0228	+65 fps	+66 fps	+67 fps	+90 fps
100 Deg	+.0387	+110 fps	+113 fps	+114 fps	+153 fps

- Once you obtain a reading of the ammunition temperature, go to the above table and select the temperature range nearest that of the ammo temp. This is not as exact a method as corrections for SR, BP and TEMP. In this training example, the ammunition temperature is the same as the air temperature (100 degrees) Note that the standard air temperature used to calculate this table is 70 degrees.
- Go from the air temp column, across to the column under the 2,840 fps title. This is your new muzzle velocity based on ammunition temperature. Note the table below. It is an extract from the calcforn for the .50-caliber SWS. Enter the new muzzle velocity in the box indicated. The rule of thumb for corrections based on ammunition temperature is:

For every 50 fps gain or loss in muzzle velocity based on ammunition temperature, add or subtract 1 MOA to the current sight setting. When the muzzle velocity is down, you will add the correction; when the muzzle velocity is down, you will subtract the correction.

- Once you have entered and determined the correction based on the above rules, enter the MOA correction in the box on the calcforn. At this point you have determined the corrections for ammunition temperature. It is important not to overlook this correction. It is a common cause of elevation errors. In the below sample, the ammunition temperature is 100 degrees.

AMMO TEMP	100 Deg.	CORR. FACTOR	+.0387
FOR MUZZLE VEL.			
NEW VELOCITY	2949 fps	MOA CHANGE FOR MUZZLE VELOCITY	-1.00 MOA
MUZZLE VELOCITY BASED ON THE TEMPERATURE =		2949 FPS	
CORRECTION TO PLACE ON SCOPE SETTING =		- 22.75 MOA	
Add all of the sight corrections calculated to this point. These are the BP, Air Temp, and Ammo Temp Corrections.		These	
FINAL SETTING ON THE SCOPE =		61.75 MOA	
Use the exact setting 84.50 - 22.75 =		Set on telescopic sight	
RIFLE TWIST CORRECTION (TRUE RANGE) =		ALWAYS LEFT MOA 1.50 MOA Left	

In this example the ammo temp is 40 degrees. This is almost the same as the Air Temp. This is common.

Note the Data.

Ammo Temp = 100 Deg. F.
New Muzzle Velocity = 2949 fps

Using the above rules of + 1 MOA for every 50-fps change, we have a gain of 110 fps or - 2.00 MOA for correction of elevation setting.

We correct by dropping 2 MOA to the Elevation Setting.

OK, we have made it quite a ways since the beginning. If you are totally lost and you have an Excedrin headache, don't feel lonely. When this class was taught in the SOTIC courses, it was taught in a two-day series. Each series was four hours long. I kept a bottle of Excedrin Extra Strength for anyone who wanted it. That included the instructor and students. We both used it frequently.

GYROSCOPIC PRECESSION OR CORRECTING FOR SPIN DRIFT

Spin drift is a by-product of gyroscopic precession caused by a right-hand twist of a rifled barrel. It occurs the same in left-twist barrels except the bullet drift is to the left. A bullet exits the bore at a tremendously high RPM. In fact, the bullet rides on a column of air as it travels downrange. In military circles, current writings on this subject treat it very lightly. Granted, most military sniping ranges are at ranges where bullet drift is of little consequence. However, when shooting at 1,500+ meters, nothing can be ignored, just as with MET and ENV conditions. The point of all of these technical corrections is that a bullet technically will not fly to the exact place you point a barrel. For our purposes, we require a 2-MOA shot group standard when the shooter is combined with the weapon and ammunition. When you get to ranges past 550 meters, this 2-MOA circle is larger than a human torso. As a result, any correctable condition such as spin drift is required for a higher pH / PK We cannot accept initial errors in our sight adjustment hoping that MET and ENV conditions will be favorable or forgiving, because they are not.

Refer to the Secondary Functions Table for the Mark 211, Mod-0 ammunition. In the far right column is the correction for spin drift. This is placed on the sights in terms of MOA. The correction is always to the left, unless for some reason you have a left-hand twisted barrel. They do exist. This is the first correction for windage on the sight that you will index. Remember it is based on true range.

BALLISTIC DATA

MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL.AMMUNITION

"Secondary Functions"

RANGE	TIME OF FLIGHT	FALL ANGLE	DRIFT (IN.)	DRIFT (MOA)	MAXIMUM INCHES	ORDINATE FEET
100M	0.11901	.03901	.039	0.00	.65637	.05470
200M	0.24552	.08582	.123	0.00	2.65990	.22166
300M	0.38126	.14177	.295	0.00	6.85051	.57088
400M	0.52454	.20697	.564	0.00	12.99890	1.08324
500M	0.67903	.28356	.946	0.25	21.84928	1.82077
600M	0.84450	.37843	1.48	0.25	34.15119	2.84593
700M	1.02171	.48120	2.16	0.25	49.47793	4.12316
800M	1.20845	.60344	3.04	0.25	69.37816	5.78151
900M	1.43374	.77114	4.25	0.50	80.58375	6.71531
1,000M	1.65911	.97636	5.87	0.50	132.2502	11.02085
1100M	1.90095	1.1911	7.73	0.50	173.6013	14.46678
1200M	2.14396	1.4251	9.95	0.75	222.0612	18.50510
1300M	2.44381	1.7612	13.07	0.75	290.3273	24.19394
1400M	2.76441	2.1492	16.93	1.00	375.6156	31.30130
1500M	3.09585	2.5829	21.53	1.25	480.1845	40.01538
1600M	3.43806	2.9931	26.47	1.50	593.1158	49.42632
1700M	3.36584	3.4052	31.87	1.75	717.8009	59.81674

THE COMPLETE .50-CALIBER SNIPER COURSE

RANGE	TIME OF FLIGHT	FALL ANGLE	DRIFT (IN.)	DRIFT (MOA)	MAXIMUM INCHES	ORDINATE FEET
1800M	3.94627	3.8027	37.58	1.75	850.3885	70.86571
1900M	4.39449	4.2163	43.89	2.00	997.5054	83.12546
2000M	4.72368	4.6552	50.93	2.25	1162.200	96.85003
2100M	5.05734	5.0994	58.44	2.50	1346.373	112.19771
2200M	5.40024	5.5701	66.87	2.75	1533.807	127.81728
2300M	5.74486	6.0461	75.81	3.00	1745.580	145.46502
2400M	6.10018	6.5504	85.63	3.25	1978.608	164.88401
2500M	6.46895	7.0916	96.49	3.50	2230.990	185.91587

If there is any portion that gives you particular trouble, go back to the beginning of the calculation, erase any work you have put on paper, clear your calculator, and begin again. Many times, the solution is found in a mistaken keystroke on the calculator. A decimal in the wrong place, accidentally reformatting your calculator, or hitting a 4 instead of a 1 while in a rush. Don't beat your head against the wall. Take a break, walk around and try again. If this doesn't work, sleep on it.

Finally we have made it through all four of the major corrections; slant angle to the target, barometric pressure, air temperature, and ammunition temperature. We also have made a correction for a little known factor; spin drift. This one is simple yet almost always completely neglected. We have gone up and down with the sight settings and we might well be somewhat confused, have a headache, or like some students I have seen, totally bewildered. Sometimes it still does it to me, so don't feel bad. Now it's time to apply all those calculations and corrections.

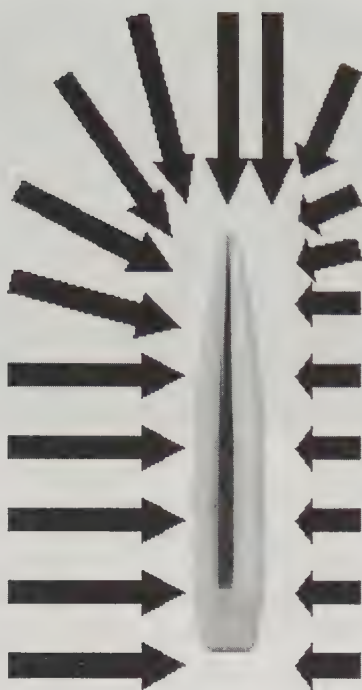
FINALIZING ALL CORRECTIONS

These calclforms are used for other classes of sniper weapons systems, including the light and medium classes of guns. When dealing with the ranges encountered in HTI, shooters may engage targets as far away as 2,000+ meters. There are a couple of factors that must be determined and corrected for. These additional corrections are:

- Windage corrections for air temperature
- Specialized wind correction process
- Point blank zero determination
- Calculated maximum effective range

Correcting the Windage for Air Temperature

This is actually simple compared to the art of determining the value of the wind itself. Throughout history, shooters of all types have used various techniques to determine the wind. Mirage is probably the most popular for snipers. This gives wind data for downrange between the gun and the target. Many competition shooters place great weight on the winds at the gun. The theory is that a bullet picks up a crosswind velocity that continues downrange and is therefore more deflected than a bullet that encounters wind only halfway to the target. That's a very strong argument. Personally, I use every bit I can get my hands on. Shooting at 1,600 meters, you must consider winds everywhere and something else. Within the last few years, much work has been done on developing a system to sense the windage conditions downrange. Lasers that sense the wind conditions are coming into their own. Another technique is to use anemometers than can transmit their data to receivers at the sniper's position.



Effects of a left to right wind on a bullet in flight.



Checking the winds.

Whatever the method that is used, a time comes for the sniper to place a correction on the scope or to hold off a distance left or right of the desired point of impact. When shooting at extreme ranges, nothing can be taken for granted. This is especially true for a military sniper that cannot fire extra rounds downrange because of a blown wind call. There is NO room for guess or error. With this in mind, we have to make another small but important correction. The windage correction for compensating for a wind downrange must be corrected for air temperature. Cold winds blow the bullet harder than do hot winds. We can calculate in inch deflections, MOA clicks, or mil holdoffs how much a bullet will deflect a specified mph increments. We do this because we know how efficient a specific bullet is in flight and with a formula we can determine how much to correct for a specified wind velocity. One can ignore correcting for air temperature at shorter ranges, say to 800 meters.

Contrary to popular belief the big .50-caliber bullet isn't all that efficient in cleaving the wind. There are a number of bullets in the civilian sector that have very high ballistic coefficients. These are mostly hand loaded ammunition that are outstanding. The military ammunition has ballistic coefficients that hover around .6000 or so. At velocities of 2,800 to 2,900+ fps, that isn't very competitive to .30 caliber or .338 caliber bullets with a BC of .7000+ at velocities over 3,000 fps. The .50-caliber bullet is a very large bullet with a huge sideways cross section—lots of surface area for the wind to push on. For example: at a range of 1,600 meters, if the air temperature is 37.6 degrees with a wind speed of 10 mph, there is a difference in the strike of the bullet of 18 inches between an air temperature of 70 degrees and that of 37.6 degrees. Not a big deal on a vehicle or a radar. A very big deal on a human target or a narrow high-value missile target.

The Specialized Wind Correction Process

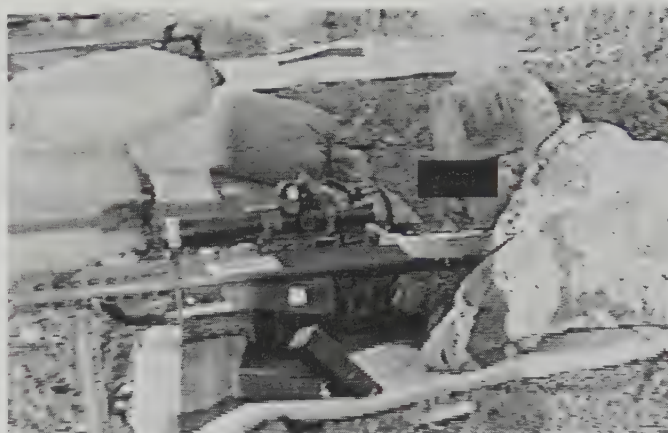
Refer to a copy of the calform. On the bottom of page 2, there is a line entry called Dominant Wind Correction. What this is referring to is a piece of data that a sniper team gathers in pre-mission planning and updates that when on the ground. For military snipers, weather data is available that would give them expected wind conditions at any time during the day on any place on the surface of the earth. For example at 1400 hours, a sniper

team may expect to encounter 12 mph winds from the NNE. These figures are based on a history of conditions combined with weather predictions for conditions that exist on the planet at the time of the weather prediction.

As the sniper team is waiting for the shot time or for the target to arrive, they continuously gather wind data. This is done for winds at the target, at the gun and anywhere in between then gun and target that they can gather wind data. Hand-held anemometers are a great help. Sometimes wind at the position is the ONLY wind data that the shooter can collect. As the team gathers wind data, they place the corrections for this data on the gun. This may be done every 5 minutes or once an hour. That is up to the team completely. But

something that must happen, especially in very long range situations, is correcting this wind data based on air temperature.

One of the problems with shooting at extreme ranges is indexing large wind corrections on the scope. Many snipers prefer to hold off a number of mils on the target. This is an excellent method for battlefield sniping. A problem occurs however when the windage holdoff is more than the number of mils available on the reticle of the scope. A 12-mph wind at 1,600 meters requires a 5-mil holdoff under standard atmospheric conditions. That's a pretty strong holdoff. And it doesn't leave any room to add



RIFLE TWIST CORRECTION (TRUE RANGE) =

DOMINANT WIND CORRECTION =

WINDAGE / TEMPERATURE CORR. FAC .

CORRECTION FOR WINDS BASED ON AIR TEMPERATURE =

MULTIPLICATION FACTOR VALUES =

DETAILED WIND CORRECTION IN M.O.A.

Left 1.50 MOA

17.00 MOA Left

1.02641

2.14

19.50 MOA Left

The dominant winds are wind data that snipers gather in pre-mission planning and in the time before the shot. Constantly update for air temperature.

17.00

X

1.02641

"yx" key

2.14 = 17.97528 rounded to
18.00 + 1.50 for twist.
= 19.50 MOA Left detailed
wind correction.

MINUTE OF ANGLE HOLDOFFS FOR MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE

RANGE X 100(M)	2 MPH	4 MPH	6 MPH	8 MPH	10 MPH	12 MPH	14 MPH	16 MPH	18 MPH	20 MPH
1500 meters	2.50	5.25	7.75	10.50	13.00	15.75	18.25	21.00	23.50	26.00
1600 meters	2.75	5.75	8.50	11.25	14.25	17.00	19.75	22.75	25.50	28.25
1700 meters	3.00	6.25	9.25	12.25	15.50	18.50	21.50	24.75	27.75	30.75

on a holdoff for last-minute winds. When you dial in the dominant wind correction (18.50 in the above example) you have more options. With the dominant wind dialed in a 12 mph the observer must track wind data as he determines it downrange or wherever he is tracking the winds.

When it becomes time to shoot, the observer makes a last-minute wind determination and either gives the shooter a "hold center" wind call or he adds/subtracts wind corrections based on the data on the gun. See the following chart for an example.

The observer, like usual, has the toughest job here. The observer's job is to calculate everything possible and only give the shooter a target, an elevation, and a windage setting. The observer must keep track of changes between the dominant winds and the final winds before the shot is taken. This must happen very quickly. Essentially it is quite simple. If dominant winds are 12 mph and that data is on the gun, the observer only tracks wind changes from that 12 mph setting. If the winds pick up to 15 mph, the data that he gives the shooter when it's time to shoot is for a 3 mph. The would be a 4.25 mil additional holdoff. The shooter doesn't need to know that the winds changed or by how much. It doesn't matter to him. Only the correction that he needs to hold off or index on the windage knob matters.

DOMINANT WINDS @ 12 MPH = 17.00 MOA CORRECTION

+ 1.50 Left correction for Spinning Drift

= 18.50 MOA Left indexed on the scope.

Observer detects a wind decrease (steady) to 8 mph, a difference of 4 mph.

Wind correction for 8 mph at 1600 meters = 5.75 MOA

5.75 MOA = 1.75 MILS (divide 5.75 by 3.375)

Observer gives a wind call to the shooter of “Hold RIGHT 1.75 MILS”. This tells the shooter to hold right to account for a wind situation that has the winds at less than the data that is on the scope. 12 mph on the gun vs. a real condition of 8 mph. Shooter compensates with a MIL Holdoff.

An advanced technique when shooting at long-range non-moving targets is to determine the most common wind value—12 mph for example. Then index this data on the gun with corrections for air temperature and additions for spin drift. The observer then waits for the winds to stabilize at 12 mph. He then gives a “Hold center” command to the shooter, who fires the rifle.

The Point Blank Zero Process

This is a method that hunters have used for years. It is a means of engaging a target without determining the range to that target. Because you don’t determine the range, it has severe limitations. Using a point blank zero is a snap-shooting procedure. It is used when a team is moving into position or when a target has not yet appeared and the team doesn’t know where it may come from. A good example is a missile standing up at exactly the moment a hard target moves into position and there isn’t enough time to do detailed calculations. A point blank zero uses a situation where a strike anywhere in a given diameter on the target will do acceptable damage to that target. Missile targets cannot sustain .50-caliber impacts anywhere on them. Therefore the vertical height of the missiles becomes the critical diameter for determining the point blank zero range. On a deer, the PBZ is considered to be 12-14 inches. On a human target in battlefield conditions, this critical diameter is as much as 24 inches. This is up to the shooter and his needs.

This is further based on the trajectory of the bullet never rising above the top of the PBZ diameter or never falling below the bottom of the diameter circle. The following table gives target sizes. It is assumed that a strike anywhere within the given height of the target will disable that target. This also holds true for any critical component of a target that is the size of one of the Height of Target sizes in column 1. This process is simple. If a team is expected to engage a target of 7 meters in height, shooters refer to their data table and refer to their PBZ table. Looking at a target height of 7 meters, they go across to the second column zero range (950 meters). They then refer to their data table and dial in the elevation setting for that zero range (950 meters = 33.50 MOA). In column 3 is the maximum range that a target of 7 meters will be struck when the point of aim is in the center of the target. In this case that range is 1,088 meters.

This is a good technique for a team to use when moving into their final firing position (FFP). They dial in the PBZ range that corresponds to the target size of the target they are hunting. They move into position and are ready to do a snap engagement of a target that may appear (provided it is less than 1,100 meters away). If a target appears that is farther away, the observer makes a snap judgement and has the shooter shift to the top of the target for a hold point. On a 7-meter-tall target, this pushes out the maximum engagement range to 1,450 meters. Again, this is an emergency snap engagement procedure. As time allows, the team does a precise range determination and goes through the technical process of correcting for MET and ENV conditions.

POINT BLANK ZERO TABLE // .50 CAL SWS

THIS POINT BLANK ZERO TABLE IS FOR FAST AND LESS THAN PRECISE ENGAGEMENT OF TARGETS LISTED BY THEIR HEIGHT. THIS TABLE IS FOR ALL AMMUNITION IN THIS DATA BOOK *EXCEPT* FOR M-903 SLAP.

EXAMPLE: SCUD B MISSILES = 11.5 METERS LONG (ERECTED)

TO PLACE A SHOT ANYWHERE VERTICALLY ON THE MISSILE BODY, PLACE AN ELEVATION OF 36.75 MOA (1100M). MISSILES OUT TO A RANGE OF 1253 METERS (SAC) A ROUND WILL STRIKE SOMEWHERE BETWEEN THE TOP AND THE BOTTOM OF THE TARGET. OTHERWISE KNOWN AS "SNAPSHOOTING"

HEIGHT OF TARGET	ZERO RANGE	PB ZERO RANGE
1 Meter	457 M	530 M
2 Meters	600 M	700 M
3 Meters	700 M	813 M
4 Meters	777 M	900 M
5 Meters	841 M	970 M
6 Meters	900 M	1035 M
7 Meters	950 M	1088 M
8 Meters	990 M	1125 M
9 Meters	1033 M	1170 M
10 Meters	1070 M	1216 M
11 Meters	1100 M	1253 M
12 Meters	1134 M	1290 M
13 Meters	1161 M	1325 M
14 Meters	1188 M	1363 M
15 Meters	1216 M	1390 M

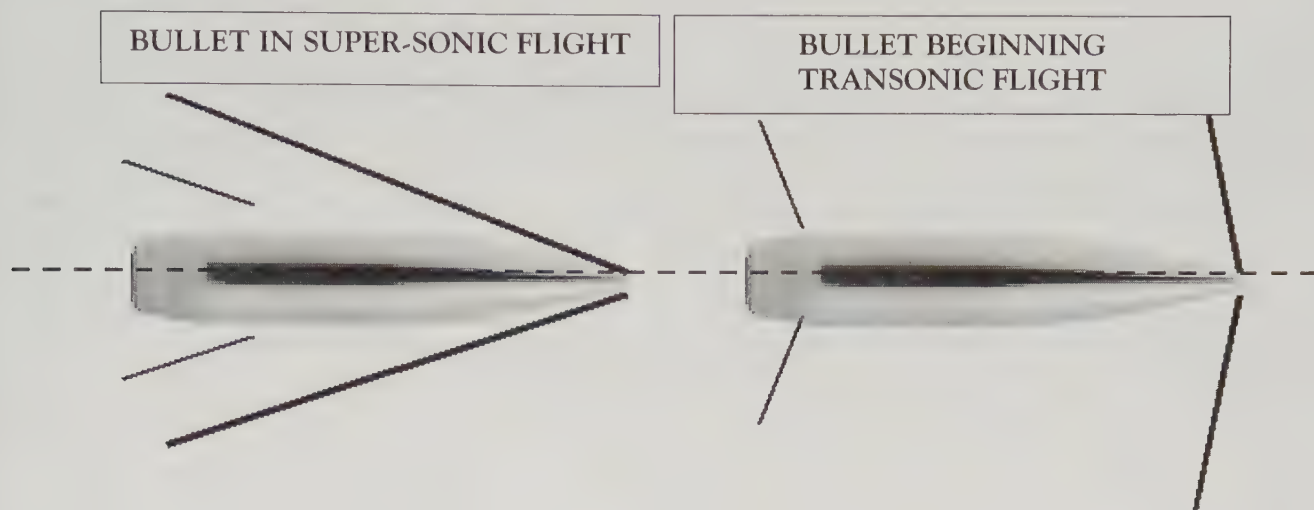
THIS METHOD WORKS WELL WHEN THERE ISN'T ENOUGH TIME TO PERFORM RANGE FINDING AND CRITICAL CALCULATIONS.

TARGETS FROM 0 METERS TO THE POINT BLANK ZERO RANGE CAN BE ENGAGED WITHOUT REGARD TO RANGE AS LONG AS THE TARGET IS NO FURTHER THAN THE POINT BLANK ZERO RANGE LISTED IN THE RIGHT COLUMN. AS TIME ALLOWS, ALL METEOROLOGICAL CONDITIONS SHOULD BE CORRECTED AND APPLIED TO THE PBZ ELEVATION DATA.

Calculating Maximum Effective Range and Supersonic Burnout

This is sure to raise eyebrows in some shooting circles. In Hard-Target Interdiction we do not use listed maximum effective ranges in military manuals. First, they are based on a totally different engagement method. They are printed for the .50-caliber M-2 MG and not a rifle. And they don't take into account 2 MOA standards of accuracy. Calculated maximum effective range is based on a standard of 2 MOA accuracy required to strike a target provided all the numbers are done right. When a .50-caliber rifle bullet leaves the barrel it is travelling at supersonic velocities. As it travels farther and farther downrange, it begins to slow down. As it slows down the supersonic shock wave begins to open up from being tight along the bullet to a point where it is perpendicular to the flight of the bullet.

As the bullet is slowing down and begins to go into transonic flight, it is fighting the "wall" of the



supersonic shockwave. Just as a fighter aircraft struggles to get through the sound barrier on acceleration, a bullet encounters the same resistance on slowing down. As it is fighting to punch through the “wall,” the bullet yaws and pitches a little bit. Anyone who has fired Federal Match 168 gr. or military M-852 at 1,000 yards has seen the result. It keyholes on the target, but not all the time. Same thing happens with any bullet after it has gone subsonic. That period of destabilization can cause the bullet to tumble. At the very least, it takes it off its original intended flight path, and is therefore unpredictable on its point of impact.

Calculating the maximum effective range does two things for the sniper team:

1. It determines if the range at which the sniper team is shooting is within supersonic range of the bullet under the measured MET and ENV conditions.
2. It tells the sniper team at what range their bullet is going to begin transonic flight. This allows them to back off if necessary or possible to a further range. If they are too far away, it tells them their minimum engagement range under measured MET and ENV conditions. This is a very useful tool in mission planning.

Look at the example part of a data book below. Supersonic burnout is at 1,125 fps at standard atmospheric conditions. Note that for the range we are shooting at the remaining velocity is only 986 fps. Were this Standard Atmospheric Conditions, we would be too far away to engage this target because of bullet instability once the bullet goes subsonic at around 1,300+ meters. But we have gained a great deal by being higher in altitude and a much lower barometric pressure. This gains us some supersonic range.

BALLISTIC DATA

MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE .50 CAL.AMMUNITION

RANGE	SUPER ELEV-MOA	SUPER ELEV-MILS	SUPER-ELEV. PER 100 METERS	TEMP. CORRECTION FACTORS	BAROMETRIC CORRECTION FACTORS	ALTITUDE CORRECTION FACTORS	REMAINING VELOCITY
1,400M	67.50	20.00	9.75	1.01782	1.03046	1.02660	1080 FPS
1,500M	78.50	23.25	11.00	1.01914	1.03299	1.02911	1024 FPS
1,600M	89.25	26.40	10.75	1.02035	1.03510	1.03145	986 FPS

For a sniper team preparing for a mission, the process of determining maximum effective range is a great planning tool. Some operational environments are extreme. High altitudes, low barometric pressures, high or low air temperatures, or just extreme engagement angles all affect the range at which the bullet begins subsonic flight. The next page is a detailed instruction on the use of the final calculations page of the calcform.

We have worked through the final step in calculating for MET and ENV conditions. In Chapter 9, “Application of Fire,” we will go a little deeper into each of the above subjects and explain some of the tricks of the trade in extreme range shooting. You now have determined all of the corrections that one can calculate.

At the end of this chapter you will find a copy of the calcform in the full process of these calculations. As you read through the information, work the problem on your calculator and see if you obtain the same solutions. This is a good method for detecting errors in your calculation process.

SUMMARY

Not enough attention is given to the effects of MET and ENV corrections. Match shooters record MET and ENV in their shooting score books and refer back to them in terms of elevation and windage settings for the range they are shooting on during that time of the year, but few know why. The reality is that you as a SOF sniper will be placed in a situation where you have no data on the MET or ENV conditions you are in and will have to calculate them. This class gave you the information necessary to make scientific, calculated correction to your sights, not merely a guesstimation based on data that was never taken in the environment your mission is taking place in.

You must now maintain these skills, as they are as perishable as shooting itself. From this point on, you will hear other shooters asking questions about why a shot went high or traveled more with the wind than expected. You now have the answers to these questions and the means to fix the problem.

Remember that when shooting up or down hill your rounds will strike high. It is because of gravity and the bullets’ linear exposure to the effect of gravity. So you correct for slant range. Your slant range will always be less than true range.

Barometric pressure above 29.53 means that there is higher air pressure and the bullet meets more resistance, therefore, you need more elevation on the rifle to compensate (pressure up, sights up). So you multiply the BP constant against the true range MOA. If it’s a pressure down, sights down situation, you divide the BP constant by the true range MOA. If there isn’t enough time to calculate this out, take a best guess. Hoping that the bullet won’t be effected is no good.

Air temperature has two effects on the external ballistics of a bullet.

- The higher the air temperature, the thinner the air so there is less drag on the bullet and the bullet will go higher. The sights must be adjusted down. Air temperature up, sights down. So we divide the temperature constant against the true range MOA setting. The colder the air temperature, the thicker the air so there is more drag on the bullet and the bullet will go lower. So we multiply the temp constant against the true range MOA setting.
- Thinner air related to hotter air will blow the bullet less in the wind than colder denser air, so less windage is needed on hot days than cold days.

Ammunition temperature has a dramatic effect on the bullet due to changes in muzzle velocity. Hotter ammunition causes more vigorous combustion and a higher muzzle velocity. The result is that the bullet will strike higher at longer ranges because its higher muzzle velocity allows the bullet to resist the air more. Cold ammunition as in wintertime causes less vigorous combustion and a lower muzzle velocity. The result is that the bullet will strike lower at longer ranges.

You will hear and see experienced high-power shooters unload and replace the cartridge in their chamber because it lay there too long. This is replaced in order to fire every cartridge at the same temp causing the same muzzle velocity. During training on the range you will be reminded to replace cartridges when they become too hot. A good rule is that if a cartridge is too hot to handle, it is too hot to shoot. For every 50-fps change in muzzle velocity, we correct by one MOA. I hope that this has been an interesting subject. If you have trouble, try again. The time taken to master this process is well rewarded.

PAGE 3 OF THE CALCFORM

FINAL TARGETING DATA	
FINAL ELEVATION SETTING	
DETAILED WIND CORRECTION	
<u>TARGETING DATA</u>	
POINT BLANK ZERO DIAMETER SIZE	
(VELOCITY - 1125 FPS AT SEA LEVEL)	
SUPERSONIC BURNOUT OF AMMO	
ENTER THE SLANT RANGE ELEVATION SETTING	
ADD THE TOTAL OF ALL CORRECTIONS FOR BAROMETRIC PRESSURE, AIR TEMPERATURE, AND AMMO TEMPERATURE AND ENTER THIS VALUE HERE.	
ADD OR SUBTRACT THE VALUE OF THE CORRECTIONS FROM THE SLANT RANGE ELEVATION SETTING AND ENTER HERE. IF THIS MOA SETTING IS LOWER THAN THE ELEVATION SETTING THAT CORRESPONDS TO THE S.A.C. SUPERSONIC BURNOUT RANGE, YOUR ROUND WILL BE SUBSONIC ALL THE WAY TO THE TARGET. YOU ARE GOOD TO SHOOT.	
IF ALL CORRECTIONS RESULT IN -MOA ON THE SIGHT, THIS IS CALLED A "GAIN RANGE" SITUATION. THIS MEANS THAT YOUR SUPERSONIC BULLET RANGE IS FURTHER THAN UNDER S.A.C. THE NEXT STEP IS TO DETERMINE THE RANGE AT WHICH THE BULLET WILL GO SUB-SONIC. TO DETERMINE THE CALCULATED SUPERSONIC BURNOUT RANGE, ADD OR SUBTRACT THE TOTAL OF ALL CORRECTIONS FROM THE TRUE RANGE ELEVATION SETTING. INTERPOLATE THE RANGE THAT CORRESPONDS TO THE SOLUTION OF THIS CALCULATION. THAT RANGE IS THE SUPERSONIC BURNOUT RANGE OF THE BULLET. IF YOU ARE CLOSER THAN THIS RANGE, YOU ARE GOOD TO SHOOT, IF NOT MOVE CLOSER OR WAIT FOR FAVORABLE CONDITIONS. EXAMPLE: TRUE RANGE SETTING: 79.25 MOA SLANT RANGE SETTING: 76.25 MOA TOTAL OF ALL CORRECTIONS = -18.25 MOA CORRECTION FINAL ELEVATION SETTING AFTER CORRECTIONS = +58.00 MOA CORRESPONDING RANGE TO 58.00 MOA = 1302.56 METERS THIS RANGE IS UNDER THE S.A.C. BURNOUT RANGE OF THE BULLET. NOW DETERMINE THE ACTUAL RANGE AT WHICH THE BULLET GOES SUBSONIC. TRUE RANGE SETTING = 79.25 MOA TOTAL OF ALL CORRECTIONS = 18.25 MOA / ADD THIS TO 79.25 MOA = 97.25 MOA CORRESPONDING RANGE TO 97.25 MOA = 1672.73 METERS TO SUPERSONIC BURNOUT.	
RE-CALCULATED ENGAGEMENT RANGE AFTER +- BP, TEMP. CORR.	SUPER-SONIC BURNOUT RANGE OF BULLET AFTER CALCULATIONS

Detailed Instructions

The Final Elevation Setting is from Page 2 of the CALCFORM. This is the setting after all corrections for air pressure, air temp. and ammo temp.

The Point Blank Zero diameter size is the size of a spot on a target or the target itself that you can accept a hit on. This may be the full height of a missile or the size of a critical component of a target.

Slant range elevation setting before any corrections figured in. Calculate the total of all changes for pressure, air temp. and ammo temp and enter here.

Add or subtract the total of all changes from the slant range elevation setting. In the chapter example, this is a negative number so you would subtract this value. Enter here.

Then refer to the data table and locate a MOA value that most closely corresponds to the corrected elevation setting. Trace across to the remaining velocity column. If this velocity is faster than 1125 fps, you are good to shoot.

Basically, if your final corrected elevation setting is smaller than your True Range setting you will gain range over Standard Atmospheric Condition sub-sonic range of that particular bullet.

PAGE 1 OF THE CALCFORM

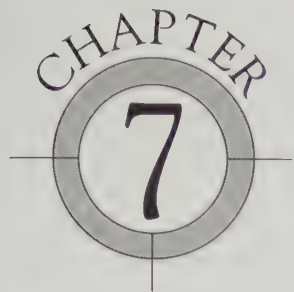
INITIAL RANGE TO TARGET =	1600 Meters	Initial True Range to Target. This represents the actual amount of AIR between the gun and the target.
TYPE AMMUNITION TO USE =	Mark 211, Mod-0	
SLANT RANGE CORRECTIONS		
ALTITUDE OF GUN = ASL	4000' ASL 1219.2024 Meters	Altitude of Position 4000 X 12 divide by 39.37 = 1219.2024 Meters ASL
ALTITUDE OF TARGET = ASL	2750' ASL 838.20168 Meters	Altitude of Target 2750 X 12 divide by 39.37 = 838.20168 Meters ASL
DIFF. OF ELEVATIONS (METERS) = 2 Methods of Slant Range Determination 1. COS Angle to TGT X True Range = Slant Range // SLANT RANGE CORR FACTOR 2. $\frac{VD}{\cos \theta}$ "ATAN" "COS" X ORIGINAL TRUE RANGE HD RESULT IS THE SLANT RANGE Factor	381.00076 Meters	Subtract the two elevations to determine the Vertical Distance (VD) 1219.20244 - 838.20168 = 381.00076 Meters Difference
	.97280 Correction	VD = 381.00076 HD = 1600 = .23813 ATAN or TAN-1 = 13.39414 Deg. Slant Angle
	1556.47934 Meters	COS 13.39414 = .97280
CORRECTED SLANT FIRING RANGE		1600 Meters Trange X .97280 = 1556.47934 Meters Srange
INITIAL ELEVATION (MOA) TRUE RANGE ALL MET. CORRECTIONS ARE BASED ON THIS RANGE	89.25 MOA	
ELEVATION SETTING SLANT RANGE INDEX THIS SETTING ON THE SCOPE (MOA)	84.57153 MOA	
CORRECTIONS FOR BAROMETRIC PRESSURE		
BP UP - MULTIPLE /// BP DOWN - DIVIDE // STANDARD BP = 29.53 In. Hg.		
MEASURED BAROMETRIC PRESSURE OR Hg. USE THE STANDARD FOR THE ALTITUDE = YOU ARE AT, IF YOU HAVE NO BAROMETER	24.68 In.	BP CORRECTIONS True Range = 89.25 MOA Divide by 1.03510 "yx" key 4.85
BP CORRECTION FACTOR FROM TABLES =	1.03510	= 75.49979 MOA new sight setting or - 13.75 MOA for adjustment due to air pressure.
SUBTRACT THE MEASURED BP FROM 29.53 AND ENTER THIS NUMBER HERE. MOA CORRECTION TO PUT ON SIGHT SETTING	4.85	
THE ELEVATION SETTING -13.75051 MOA	NEW ELEVATION BASED ON BP 75.499749 MOA	
CORRECTIONS FOR TEMPERATURE		
TEMP UP - DIVIDE /// TEMP DOWN - MULTIPLY		
INSERT TRUE RANGE ELEVATION DATA SETTING. THIS IS THE "UNCORRECTED" TRUE RANGE SETTING.	89.25 MOA	
STANDARD OF 59.0 DEGREES FAHRENHEIT MEASURED TEMPERATURE OR USE THE STANDARD AIR TEMPERATURE FOR THE ALTITUDE YOU ARE AT. IF OBVIOUSLY IN ERROR WITH TABLE, TAKE A GOOD GUESS.	100 Deg. F.	TEMP CORRECTIONS Note the change in this form from previous versions of the CALCFORM that have been used. Beginning elevation setting for calculations is the True Range Sight setting. Enter the measured barometric pressure or the standard BP for the altitude at which the gun is if you cannot

PAGE 2 OF THE CALCFORM

TEMPERATURE CORRECTION FACTOR → MULTIPLICATION FACTOR VALUES → + OR - MOA TO APPLY TO THE ELEVATION SETTING -7.07558 MOA	1.02035 4.10 MINUTES OF ELEVATION 82.17442 MOA	Begin calculations by entering the Trange elevation setting on the calculator. 89.25 divide by 1.02035 "yx" key 4.10 = 82.17442 MOA or a drop in elevation of -7.00 MOA
TRUE RANGE = 89.25 MOA	SLANT RANGE 84.50 MOA	
CALCULATE ALL CORRECTIONS FROM THE RANGE ELEVATION. RE-CALCULATE FOR VELOCITY CHANGES DUE TO AMMO TEMPERATURE	APPLY ALL CORRECTIONS TO THE SLANT RANGE AFTER CALCULATED. +/- FOR BP CORR. = -13.75 MOA +/- FOR TEMP. = -7.00 MOA	After the corrections are computed for Barometric Pressure and Air Temp determine the actual sight change (1/4, 1/2, or Full Minute of Angle Changes) and enter these numbers in the boxes indicated.
AMMO TEMP 100 Deg.	CORR. FACTOR +.0387	AMMO TEMP CORRECTIONS Enter the Ammo Temp, the Correction Factor (if needed) and the new muzzle velocity.
NEW VELOCITY 2949 fps	MOA CHANGE FOR MUZZLE VELOCITY -2.00 MOA	
MUZZLE VELOCITY BASED ON THE TEMPERATURE	2949 fps	
CORRECTION TO PLACE ON SCOPE SETTING = Add all of the sight corrections calculated to this point. These are the BP, Air Temp, and Ammo Temp Corrections.	-22.75 MOA	Enter the Minute of Angle correction for the new muzzle velocity.
FINAL SETTING ON THE SCOPE = Use the exact setting: "7" + 3 MOA	61.75 MOA	Add the total of all corrections for BP, Temp, and Ammo Temp, Enter here.
RIFLE TWIST CORRECTION (TRUE RANGE) =	Left 1.50 MOA	
DOMINANT WIND CORRECTION =	17.00 MOA Left	
WINDAGE / TEMPERATURE CORR. FAC . CORRECTION FOR WINDS BASED ON AIR TEMPERATURE =	1.02641	
MULTIPLICATION FACTOR VALUES =	4.10	
DETAILED WIND CORRECTION IN M.O.A.	16.75 MOA Left	Enter final sight setting for your type of optical sight.
		The dominant winds are wind data that snipers gather in pre-mission planning and in the time before the shot. Constantly update for air temperature. Example based on 100 deg. 17.00 divide by 1.02641 "yx" key 4.10 = 15.27683 MOA rounded to 15.25 = 1.50 for drift = 16.75 MOA

PAGE 3 OF THE CALCFORM

FINAL TARGETING DATA		<u>Detailed Instructions</u> The <u>Final Elevation Setting</u> is from Page 2 of the CALCFORM. This is the setting after all corrections for air pressure, air temp. and ammo temp. The <u>Point Blank Zero diameter size</u> is the size of a spot on a target or the target itself that you can accept a hit on. This may be the full height of a missile or the size of a critical component of a target. <u>Slant range elevation setting before any corrections figured in.</u> Calculate the total of all changes for pressure, air temp. and ammo temp and enter here. Add or subtract the total of all changes from the slant range elevation setting. In the chapter example, this is a negative number so you would subtract this value. Enter here. Then refer to the data table and locate a MOA value that most closely corresponds to the corrected elevation setting. Trace across to the remaining velocity column. If this velocity is faster than 1125 fps, you are good to shoot. Basically, if your final corrected elevation setting is smaller than your True Range setting you will gain range over Standard Atmospheric Condition sub-sonic range of that particular bullet.
FINAL ELEVATION SETTING	61.75 MOA	
DETAILED WIND CORRECTION	16.75 MOA Left	
<u>TARGETING DATA</u>		
POINT BLANK ZERO DIAMETER SIZE	7 Meters	
(VELOCITY - 1125 FPS AT SEA LEVEL) SUPERSONIC BURNOUT OF AMMO	1381.75 Meters SAC	
ENTER THE SLANT RANGE ELEVATION SETTING	84.50 MOA	
ADD THE TOTAL OF ALL CORRECTIONS FOR BAROMETRIC PRESSURE, AIR TEMPERATURE, AND AMMO TEMPERATURE AND ENTER THIS VALUE HERE.	-22.75 MOA	
ADD OR SUBTRACT THE VALUE OF THE CORRECTIONS FROM THE <u>SLANT RANGE</u> ELEVATION SETTING AND ENTER HERE. IF THIS MOA SETTING IS LOWER THAN THE ELEVATION SETTING THAT CORRESPONDS TO THE S.A.C. SUPERSONIC BURNOUT RANGE, YOUR ROUND WILL BE SUPERSONIC ALL THE WAY TO THE TARGET. YOU ARE GOOD TO SHOOT.	61.75 MOA	
IF ALL CORRECTIONS RESULT IN -MOA ON THE SIGHT, THIS IS CALLED A "GAIN RANGE" SITUATION. THIS MEANS THAT YOUR SUPERSONIC BULLET RANGE IS FURTHER THAN UNDER S.A.C. THE NEXT STEP IS TO DETERMINE THE RANGE AT WHICH THE BULLET WILL GO SUB-SONIC. TO DETERMINE THE CALCULATED SUPERSONIC BURNOUT RANGE, ADD OR SUBTRACT THE TOTAL OF ALL CORRECTIONS FROM THE <u>TRUE RANGE</u> ELEVATION SETTING. INTERPOLATE THE RANGE THAT CORRESPONDS TO THE SOLUTION OF THIS CALCULATION. THAT RANGE IS THE SUPERSONIC BURNOUT RANGE OF THE BULLET. IF YOU ARE CLOSER THAN THIS RANGE, YOU ARE GOOD TO SHOOT, IF NOT MOVE CLOSER OR WAIT FOR FAVORABLE CONDITIONS.		
EXAMPLE:	TRUE RANGE SETTING: 79.25 MOA SLANT RANGE SETTING: 76.25 MOA	
TOTAL OF ALL CORRECTIONS = -18.25 MOA CORRECTION		
FINAL ELEVATION SETTING AFTER CORRECTIONS = +58.00 MOA CORRESPONDING RANGE TO 58.00 MOA = 1302.56 METERS		
THIS RANGE IS UNDER THE S.A.C. BURNOUT RANGE OF THE BULLET. NOW DETERMINE THE ACTUAL RANGE AT WHICH THE BULLET GOES SUBSONIC.		
TRUE RANGE SETTING = 79.25 MOA TOTAL OF ALL CORRECTIONS = 18.25 MOA / ADD THIS TO 79.25 MOA = 97.25 MOA		
CORRESPONDING RANGE TO 97.25 MOA = 1672.73 METERS TO SUPERSONIC BURNOUT.		
RE-CALCULATED ENGAGEMENT RANGE AFTER +/- BP, TEMP. CORR.	SUPER-SONIC BURNOUT RANGE OF BULLET AFTER CALCULATIONS	
1341.025 Meters Eff. Range	1800+ Meters Burnout	



Range Determination Methods and Procedures

Range determination has been commonly referred to as range estimation in instructional materials in the past. This is because for the most part, it is an estimation at best. In this chapter, we are going to discuss some of the standard range estimation methods and the problems with those methods. In staying with the tradition of this book, accepted methods are going to come under fire because accepted methods aren't good enough for extreme range shooting. It isn't good enough, however, to just blow holes in current methods—other methods must be offered in their place.

Before we get into the methods used in range determination, we should understand why we must do this. Most people know that you must determine the range because of the trajectory of the bullet. Shooters know that if you estimate short, the bullet will go short. Estimate long and the bullets will fly over the top of the target. In *TC 31-20-4: Special Operations Sniper Training and Employment*, the subject of danger space is covered in a section on application of fire. While technically this is an application of fire subject, it applies directly to range determination. For the sniper and HTI operator, the danger space figure is used for determining the level of accuracy of his range determination. There are three critical pieces of information that are tied directly to range determination and the trajectory of a bullet in flight. These are:

**DANGER SPACE
DANGER RANGE
SWEPT SPACE**

The term danger space has been given many different definitions. I will quote a few from the *Naval Gunnery Text, 1917*, where it is described as follows.

“By the term “danger space” is meant an interval of space, between the point of fall (where the round strikes the ground) and the gun, such that the target will be hit if situated at any point in that space. In other words, it is the distance from the point of fall through which a target of a given height can be moved directly towards the gun and still have the projectile pass through the target.”

From TC 31-20-4, October 1996: "The falling branch of the trajectory also contains a danger space. The danger space of the falling branch is the point where the bullet falls into the height of the target and continues to the ground."²

Both of these definitions can be a little difficult to follow, so let me try to provide another definition of danger space. "Danger space is a horizontal measurement expressed in yards or meters. As the bullet goes past maximum ordinate and travels downward toward impact with the ground (ignoring the target), the danger space measurement begins at the point where the bullet is equal to the top (height) of the target and continues to when the bullet impacts the ground (again, ignoring the target)."

There are a few factors that the danger space dimension are based on. These are:

- Height of the barrel off the ground. (In these tables in this book, the barrel height is set at 6 inches off the ground. This only matters in ranges to about 700 yards. At the ranges used in HTI operations, this factor is irrelevant.
- Height of the target. This figure is used two ways. There is the overall height of the target. With missile targets this figure is OK because a missile cannot sustain a hit anywhere on it without sustaining some kind of damage. On targets where there must be a specific point of attack, the size of this particular object becomes the height of the target. Whereas a 6-foot (1.83 meter) tall man would appear to have a danger space dimension of 137 meters at a 1,000 meter shot with .50-caliber, Mark 211, Mod-0 ammunition, the 137 meter figure isn't accurate. The reason is that we can't accept a hit anywhere on a human target and expect to kill him. There is 30-inch bracket on the human that will result in a kill or at least a totally incapacitating shot. This 30-inch (.762 meters) figure becomes the height of the target. We also use a figure of 2 MOA for anti-personnel shooting. An example is seen below:

DANGER SPACE- 20 INCH KILL ZONE M118SB			
RANGE	35 IN.	55 IN.	2 MOA
100 M	POINT BLANK ZERO		114 M
200 M	POINT BLANK ZERO		77 M
300 M	320 M	1034 M	62 M
400 M	178 M	510 M	54 M
500 M	105 M	274 M	44 M
600 M	73 M	179 M	38 M
700 M	50 M	118 M	31 M
800 M	37 M	85 M	26 M
900 M	27 M	63 M	22 M
1,000 M	21 M	48 M	19 M

Using a table for the M-24 firing M118 Special Ball and a 2 MOA kill zone, you can see that the allowable error for range determination is only 19 meters. When your point of aim is at midpoint from the ground to the top of the head, this 19-meter bracket is split 9.5 meters in front of the target and 9.5 meters behind the target. Still sound easy?

- The shape of the trajectory of the shot. Basically, this is how flat the bullet flies in its trajectory. The M-118 military cartridge has a maximum ordinate of 18 feet 4 inches (under SAC) above the line of site for a 1,000-meter shot. If a shooter were using a .50-caliber rifle with Mark 211, Mod-0 ammunition, this bullet's trajectory is 14 feet 3 inches above the line of sight. This is a considerable gain over the M118

cartridge. Many shooters are of the opinion that the .50-caliber bullet is very flat shooting. The .300 Winchester Magnum has a better trajectory depending on the bullet/load combination used. The author's heavy bullet load has a 220 gr. Sierra MK bullet at 2820 feet per second. The maximum ordinate of this load is only 10 feet 1 inch above the line of sight.

- The angle from the gun to the target. This is basically a function of the height of the gun above the ground. The higher the gun is above ground to target level, the smaller the danger space figure will be. The closer to the ground the rifle is, the longer the danger space dimension.
- The slope of the ground on which the target is standing. This angle does not affect the dimension of the danger space but it does affect a factor known as Swept Space. Swept space is addressed in Chapter 9, "Application of Fire."

How this works is like this. Let's say that the team is in its mission-planning process and they have excellent imagery of the target and the terrain around the target. They have picked out three potential final firing points (FFP). As the team examines this imagery they are able to lie out a rough range scale from their proposed FFPs to the target. They have three proposed FFPs and have determined the rough range to the target. At this point, these FFPs are selected without regard to MET and ENV conditions. As the planning process proceeds, these conditions will be initially planned in. The shooters consult their data tables for the danger space of their selected round of ammunition.

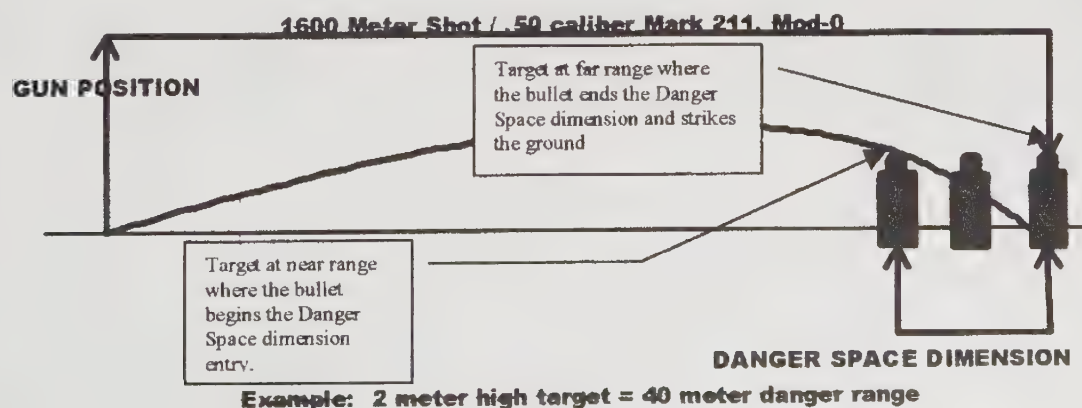
Their specified target is a component of a larger target. The overall target is 8.5 meters tall. The specific component for attack is 2 meters tall and .85 meters wide. This is a target width of 2.10 MOA for 1,400 meters. That's kind of tight. They determine the danger space for these ranges for both of these height specifications.

FFP #1: 1400 meters / 2 meters = 58 meters DS / 8.5 meters = 275 meters DS

FFP #2: 1600 meters / 2 meters = 40 meters DS / 8.5 meters = 185.5 meters DS

FFP #3: 1800 meters / 2 meters = 31 meters DS / 8.5 meters = 136.5 meters DS

You can see from the above data that there is a huge difference in the danger space figures for the 2 meter component versus the 8.5 meter overall height of the target. Remember that the point of aim for the 2 meter component is going to be center of mass. This means that the operators will split that danger space figure in half. Under standard atmospheric conditions (SAC), the shooters will have to shoot the 1,400 meter position so the bullet will be supersonic all the way to the target. The danger space figure for that 1,400 meter shot on a 2 meter tall target is 58 meters. Divide this in half and you get an allowable error of only 29 meters in the range determination. This is only 2.07 percent of the true range to the target.



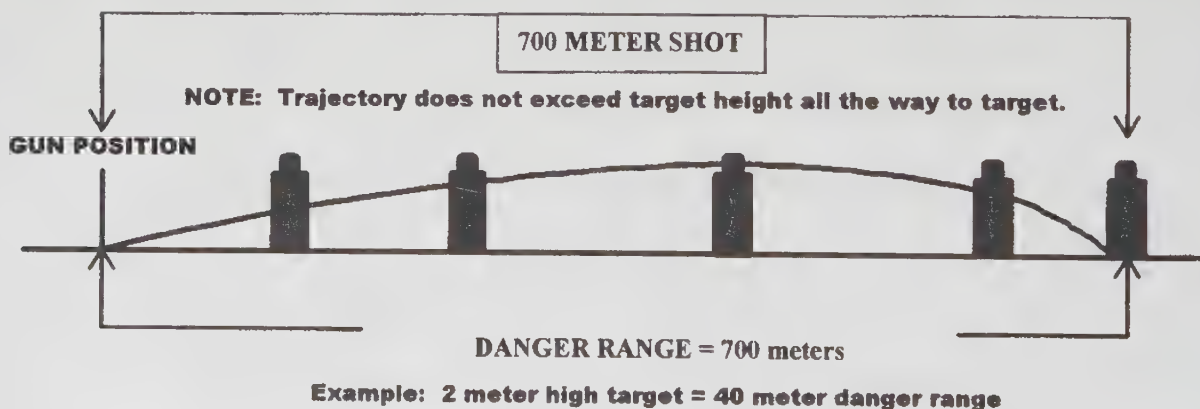
DANGER SPACE OF SELECTED TARGET SIZES (METERS) MK-211, MOD-0

RANGE	1M	2M	3M	4M	5M	6M	7M	8M	9M	10M	11M	12M	13M	14M	15M
500M	500														
600M	600														
700M	209	700													
800M	159	234	800												
900M	120	175	900												
1000M	96	137	219	1000											
1100M	76	108	168	233	1100										
1200M	68	96	149	206	1200										
1300M	50	70	108	147	188	231	275	1300							
1400M	41	58	88	120	152	186	221	257	294	1400					
1500M	34	48	73	98	125	152	180	208	237	267	298	1500			
1600M	29	40	61	83	105	127	150	174	197	222	247	272	298	324	1600
1700M	25	35	53	72	90	108	129	149	169	189	210	231	253	275	297
1800M	22	31	46	62	78	95	111	128	145	163	180	198	216	235	253
1900M	19	27	41	55	69	83	97	112	127	142	157	173	188	204	220
2000M	17	24	36	49	61	74	87	100	113	126	139	153	166	188	194
2100M	15	22	33	44	55	66	77	89	101	112	124	136	148	160	172
2200M	14	20	29	39	49	60	70	80	91	101	112	122	133	144	155
2300M	13	18	27	36	45	54	63	73	82	92	101	111	120	130	140
2400M	12	16	25	33	41	50	58	67	75	84	92	101	110	119	128
2500M	11	15	23	30	38	45	53	61	69	77	84	92	100	108	117

DANGER SPACE IN THIS ZONE IS REPRESENTED BY THE RANGE TO THE TARGET. MAXIMUM ORDINATE DOES NOT EXCEED THE HEIGHT OF THE TARGET. THIS IS REFERRED TO AS THE DANGER RANGE.

This is an appropriate time to inform the reader of the allowable error for range estimation used at the SOTIC at Fort Bragg. Their allowable error when using the mil relation technique is 10 percent of the true range, or 140 meters. Using that standard, the shooters could hit the target, but not necessarily in the critical component area.

Danger range is a term used to describe a part of the trajectory where the bullet is traveling below the height of the target. This may occur both before and after maximum ordinate. In cases where the maximum ordinate is lower than the height of the target, the entire distance from the gun to the target is danger range.



Refer to the table above. Note that in the field of the table that is blank there is a statement about danger range. Any target heights that are listed across the top, that are cross-referenced with the range on the left side, that fall into this field are danger range targets. What this also means is that if you have an elevation setting that

corresponds to the range on the left and has a target height in the open field, the trajectory of the shot never is higher than the height of the target. This allows the shooters to invoke a method called reverse image zero.

The major difference between danger range and danger space (as it applies to extreme-range shooting) is that with danger space there is a portion of the trajectory where the bullet has risen above the height of the target. It is because of this high flight that the bullet will also be on a steeper fall angle on the final approach to the target. The higher this ordinate, the steeper the fall angle, resulting in a shorter danger space figure. Ultimately, this means that the range to the target must be much more accurate than a trajectory with a low maximum ordinate. It is important to note that many of these factors are minimal or inconsequential in normal military sniping ranges of 600 meters or less. Many snipers have never had to operate in conditions that require this analytical approach to sniping. Once exposed to this environment, this information becomes critical.

Swept space is a figure that is also covered more in depth in Chapter 9. The definition of swept space is a horizontal measure that does change with the lay of the ground. Swept space is the linear measurement of the cone of fire created by shots placed at the top of the target and those placed at the bottom of the target. This is a little difficult to put into words. There are two rules that apply to swept space versus danger space:

1. On ground that is rising in front of the shooter, the swept space dimension will decrease.
2. On ground that is falling away from the shooter or sloping downhill, the swept space dimension increases and may easily continue for hundreds of meters.

Refer to Chapter 9 for a drawing that depicts this effect of swept space on rising and falling ground.

This book is as much about the subject of extreme range shooting as it is about Hard-Target Interdiction. There is one major difference between competition shooting where long ranges are involved (600 to 1,000 yards) and military sniping. This major difference is the subject of this chapter. The previous five pages have been an explanation of some factors that affect the requirement for precision range determination. Finding the range to the target is arguably the most important and the most difficult part of unknown distance shooting. Another factor that is difficult is wind reading. Snipers must determine the range to the target, sometimes to a level of 2 percent of the true range of the target. What's amazing is that in the face of this very tough requirement, most of the military and civilian sniper manuals out there only give this subject general treatment.

The same methods have been used for years without much modification. The only real change in the last few years is the advent of the laser range finder. Their cost nowadays makes them an easy option for military and police units. Some individuals can also own these systems. More about lasers later. TC 31-20-4 give this subject 10 pages of attention. It is a rehash of the Army manual TC 23-14, which gives the subject five pages. A Special Operations handout that led to TC 31-20-4 goes on for five pages also. The Naval Special Warfare Group No. 1's manual is a copy of TC 23-14. These are fine references and cover some very good information. The problem with military manuals is that they tend to use lists as checklists and don't offer a lot of supporting information or explanation about why the things are the way they are. Many times this is because the instructors themselves don't exactly understand what it is they are passing on to the student sniper. Military sniper instructors (don't get mad guys, I did it too) only pass on information that they are handed. Along the way, some different methods and techniques do evolve. This happens with some solid research and sometimes it doesn't.

There are some shooting methods that allow the sniper to virtually ignore the range to the target out to as far as 900 meters depending on the gun and ammunition load used. Military snipers are limited to their issued ammunition. These methods are further addressed in Chapters 9 and 10. I am going to address the traditional methods of range-finding because they do have their applications, though they are quite limited when shooting at these extreme ranges. An explanation is offered with each method as to why it does or does not work for extreme-range shooting.

There is another sound reason for precise determination of the range to the target. In Chapter 6 you learned how to correct the true range to a slant range setting when there is a slant angle to the target. Corrections for barometric pressure and air temperature are based on the true range to the target. When you correct the true range for slant angle and then start the corrections for MET and ENV conditions you will induce huge error if the range determination is far off. If you estimate long, your shot will miss even worse because the corrections for MET and ENV are based on that long range. If you determine the range short, you won't correct enough. The paradox is that when you estimate short and your corrections for MET and ENV conditions are done, you will actually come closer to hitting the target. This is because you are calculating using smaller (range) numbers than you are when determining the range long or exactly on the range. In the end, you'll miss both ways.

ANALYSIS OF A MISSED RANGE SCENARIO

The conditions below are for a shot that was estimated both long and short to show the effect of missing the range determination. When estimating smaller targets at extreme ranges, little errors result in huge misses. For example, a human being that is 6 feet (1.83 meters) tall using a standard mil relation formula has the following potential error:

1.83 meter target milled at 1.6 mils / Range = 1,143.75 meters
 1.83 meter target milled at 1.5 mils / Range = 1,220.00 meters
 Difference = 76.25 meters
 True range = 1,181.875 meters

This is a result of only 1/10th of a mil error. That's a damn small error. The most common error is 1/4 mil. That 1/10th-mil error resulted in a 75-meter range error. The danger space figure for putting a shot into a 1 meter box at that range with a .50-caliber rifle is only 34 meters split in half when aiming center mass. This is an allowable error of 17 meters. If you split the above error in half you get 38.13 meters.

Error of .10 mils at 1181 meters = shots both long and short.

The sniper determining the range would have to have a mil reading of 1.55 mils. Think that is very realistic?

Determining the range to the target is done for two different reasons for tactical operations. First, any operator on the team determines the quick range to a target because that target may be a threat that requires some form of immediate suppression. For the sake of this book and chapter, we will call these fast ranging techniques range estimation. A likely scenario that requires a fast estimation is when the team is patrolling into their target area and they come close to an enemy patrol that has a chance of compromising them. A quick range to target is determined using non-precision methods that allow the shooters to use a point blank zero method of the reverse image zero method to quickly engage these types of targets.

The second type of range-finding method is when you use precision instruments and methods to determine a range to the target that is as accurate as possible. This will be referred to as range determination. A scenario that uses range determination techniques is when the team is in the FFP and they are determining the precise range to a target or a location where the target is expected and they are going to perform a sniper ambush. The rest of this chapter is dedicated to the different methods and some of the problems with those methods of range estimation and range determination. Range estimation methods are the same as they are in the different military manuals. I will expand on the information that is provided in those manuals. Finally, we will deal with laser range finders and their associated problems.

METHODS AND ANALYSIS OF RANGE ESTIMATION

For the purposes of Hard-Target Interdiction, range estimation is not accurate enough to engage targets that are 1,500 meters or more away. There are some good tactical reasons to do a rough estimation of the range to the target: for engaging targets that are an immediate threat to the team, directing Close Air Support, determining if enemy fire is effective or not based on the range from the good guys to the bad guys, and the list goes on. A problem that exists with these rough estimation techniques is that they require a great deal of sustainment training to keep the operator good at estimating the range.

Factors that Affect Visual Range Estimation

There are a lot of rules you must apply, especially when estimating the range with the naked eye. Estimating by eye happens to be 4 of the 6 methods that are covered here and in the military manuals. Here are these critical factors that one must consider when taking a guess at the range to the target:

Nature of the target

- “APPEARS CLOSER” Objects with a regular outline, like a building or a non-camouflaged vehicle. This is because they contrast with their background. This contrast makes them appear larger and therefore closer to you. This changes when there is a bright light behind the object. This bright light blurs the defined edges of the target and it appears smaller and therefore farther away. When these objects with a well-defined edge are brightly lit on their face, they still will appear closer, only more so as compared to conditions when they are not brightly face-lit.
- “APPEARS CLOSER” Targets that contrast with their backgrounds. Do not confuse this with objects with a well-defined edge. Again, when there is a bright light behind these objects, they will appear farther away because of loss of definition of their edges.
- “APPEARS FARTHER AWAY” A partially exposed target will appear farther away because it appears smaller than a target that is fully exposed. Try it sometime. Have a guy stand fully exposed at 500 meters and have a guy stick only his head and shoulders out right beside him at the same range. Good optical illusion.

Nature of the terrain

This deals with the ground around the target and between the target and the observer. This also ties in heavily with the other two factors and cannot be considered independent of them.

- “APPEARS CLOSER” Targets appear closer when viewed over smooth terrain such as sand, snow, or water. Again consider the impact of the other rules. If that target has good high contrast, it will appear even closer. However, if it has irregular outline, these two effects may be negated.
- “APPEARS CLOSER” Targets appear closer when viewed across a depression or low ground. Light conditions have a huge effect on this also. Backlit targets on the far side of a depression will appear extremely far away. This is compounded because of the void of objects between the target and the observer. Add to that the obscured edges of the target because of the backlit condition and they appear very small.
- “APPEARS CLOSER” Targets that are uphill from an observer will appear closer. This is a little tough, though. Light is bound to become part of the factor when you are dealing with sloping terrain. Targets that are uphill with bright light or the sun behind them will look much farther away. On this rule, if the target has terrain behind it, it will appear closer. If that same target has skyline and no terrain behind it, this is when it will look farther away.
- “APPEARS CLOSER” Targets that are located along a long straight road or railroad tracks look much closer. Targets that are located between two sets of treelines or between rows of buildings appear much closer than they are.

- “APPEARS FARTHER AWAY” Targets that are downhill appear farther away. These targets will almost never be backlit. An important point about light affects this situation, however. When the target is downhill, the target is bound to be facelit from the sun or other bright lights. This has the effect of making the target look closer and therefore the two effects frequently negate each other.

Light conditions

The general rule is: The more clearly a target can be seen, the closer it will appear.

- “APPEARS CLOSER” When the target is in full sunlight it will appear closer than the true range or than when that same target is viewed through smoke, rain, and fog, or at dusk.
- “APPEARS CLOSER” When the sun is behind the observer, targets and other objects will appear closer. This also ties in with the rule on nature of the target. Keep in mind that some of these conditions may cancel each other out. The sun may be behind you, but if it’s well camouflaged, the two conditions tend to negate each other.
- “APPEARS FARTHER AWAY” When the sun is behind the target. This can also tie in when the target has clearly defined edges. Those two conditions tend to negate each other and the range is what it appears to be. However, if the sun is behind a well-camouflaged target, it will appear a very long ways away. So while some effects may negate each other, other effects will compound the problem.
- “APPEARS FARTHER AWAY” Targets that are viewed under limited light conditions, such as through smoke, rain, and fog or at dusk.
- “APPEARS FARTHER AWAY” Targets at night will 95 percent of the time appear much farther away than they are. An interesting point is that when using the precision methods that follow this section, shooters also tend to come up with numbers that are greater than the real range to target. All operators must determine their limitations for estimating range at night. The author has seen visual estimation techniques be off as much as 75 percent of the true range. As previously stated, these estimations are always long.

All these conditions affect the estimation of range by using naked-eye techniques. They can be mastered, however. Frequently sniper students who are required to estimate the range within only 25 percent of the true range blow this entirely. This is because they ignore all of the above effects or they forget the combinations that negate or enhance each other. The key is light conditions. Almost always when the lights are brighter behind the target, they will appear farther away. This is true regardless of the nature of that target or the nature of the terrain itself. If you remember only one point, remember the light condition effects. For the readers out there that are following along with a military manual or other information source on range estimation, I am leaving out a couple of methods. These are the paper strip and the bracketing methods. For the intent of this book, these have little practical value. It isn’t likely that an operator will pull out a map and lay down a paper strip to the point where he thinks the enemy shooter is. Bracketing is an indirect fire technique that also has little use for snaphooting and breaking contact under enemy fire.

100 Meter Visual Unit of Measure and Appearance of Objects Techniques

While these two techniques are usually listed separately in other manuals they are lumped together in this manual. The reason is that the 100-meter unit of measure is a very poor method, as it stands alone, meaning open featureless terrain. When you add an object downrange this method is much more viable. But when you add an object, the appearance of objects method becomes heavily involved in the process.

This is what most people do when they look downrange and say, “I think it’s 300 meters.” It’s guesswork with some scientific mental calculation for the nature of light, terrain, and the target. There is a suggested learning path to become familiar with this technique. This can take some time, but it is well worth the learning process.

RANGE DETERMINATION METHODS AND PROCEDURES

1. Go to a football field and place a full-size human silhouette at the end of the end zone. Remember this is based on 100 meters. If you prefer yards then place it on the goal line. If you don't have a football field, measure 100 yards on flat featureless ground. Try to procure a target that is a full size image of a human target. If these are not available, dress up the cardboard silhouette in the uniform that is common to your enemy.
2. Stand off 100 yards or meters, initially on a clear sunny day. Take notice of your ability to see this target. Do it under different light conditions and take notes on what you can see and what you can't under the different conditions. This method ties in very much with the appearance of objects method. Have your rules that are listed above on light conditions and the nature of the target. Take special note of the head features and what you can see of these at this base range of 100 meters. Note the changes that take place on the target as the light goes across the sky. Then do this on a foggy day, rainy day, and hazy day and from the short transitional period from day to dusk and from dusk to full dark. Finally, view this target under conditions of moonlight and different percentages of illumination.
3. While you are doing this, write down what you think the range appears to be. If you don't want to commit to numbers, write down if it appears to be farther or nearer than 100 meters (yards). You know the range to the target, so note the subtle differences that make that target look long and short.
4. Go to an open area and place the same target or whatever object you used at 200 meters and observe it under these conditions. Note the appearance of that object. Note what you could see at 100 meters and you can no longer see at 200 meters. When you have this down at 200 meters, then do the same at 300, 400 and finally at 500 meters. Though this is recommended only to 500 meters, some individuals can push the envelope farther out and under certain light conditions (usually the conditions that make the object look closer) you can push to 800 meters. Concerning the NOTE below. Put a 1 MOA (2 inches at 200 yards or 5 inches at 500 yards) disc that contrasts with the target on the chest of that target at these different ranges and note your ability to see that disc with the different light conditions. The nature of target and terrain won't affect the appearance of this disc. Only light conditions will affect it.

NOTE: The human eye with 20/20 vision can clearly see objects that are only 1 MOA or larger. These are objects that have good contrast with their background. A good example is a white target pasty on a green or black target.

5. Once the flat terrain and varying light conditions method is mastered, proceed to the next phase of this training. Take your target and begin changing the terrain that the target is setting in. Do not begin setting the target at an unknown distance yet. Keep setting them at 100 meter intervals. If you are getting comfortable with your method, begin pushing out to 600 or even 800 meters.
6. Do step 5 at night. Note the percentage of illumination and record this data. Push the target as far as you can in 100 meter brackets until you can no longer see it under those illumination conditions and note this range.
7. Finally, begin doing the above steps on unknown distances during daylight and during periods of limited visibility. Remember fog, rain, haze, and the biggest killer of all, those transitional periods from daylight to dusk and from dusk to dark. That short 30-minute period is tough on visual range estimation. That also happens to be around the traditional times of "stand to" for the military types out there.

Final Note. This method is excellent for operators doing a quick determination to a threat target. It takes a good deal of time to master. If you have come under fire, combining this method with the "crack-thump" or sound of burst method, it becomes even more accurate. It is very important to note the conditions and your apparent ability to identify the disc at the different ranges under the conditions as they exist at the time. Note whether you estimated long or short and then note what you think affected your decision. If you live close to open fields, stick several targets in the ground at 100 meter brackets. Note the changes that happen visually to the appearance of these targets. Do not put these sustainment training targets at unknown distances.

Speed of sound

The approximate distance to an enemy can be determined by the time it takes the speed of the sound from a gunshot, explosion, etc., to reach your position. The speed of sound at sea level is 340 meters per second at 50 degrees. Since we use a standard air temperature of 50 degrees, we assume the speed of sound to be 350 meters per second. This is roughly rounded off but it works for this method. This is also called the crack-thump method, but crack-thump narrowly applies to weapons fire.

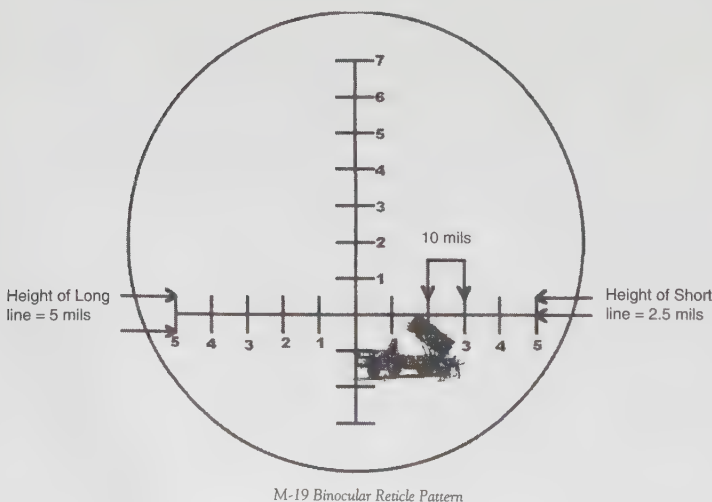
The crack is the supersonic crack of the bullet as it travels overhead. More accurately you hear the crack after the bullet has passed, but it is so quick that it is irrelevant for human hearing. The next sound, the "thump" is the boom of the gun. When an operator hears the crack of the bullet overhead, he immediately counts "one thousand, two thousand" and then boom. The rough range to the target is 700 meters. The SOTIC committee at Fort Bragg used to run as part of its sniper course a subject called "Locating the Enemy by Fire." This exercise was conducted during day and night. It started out on the KD range. The students were all in the pits clustered around one target frame. The instructor for that subject was in the pits with the students. On the range at different distance from the targets were a variety of weapons. Included were medium and heavy machine guns, .308 through .50-caliber sniper rifles, assault rifles, sub-machine guns and even pistols.

The instructor in the pits would call up the line and say a code that would result in 10-20 rounds out of a machine gun. It may result in a single shot from a sniper rifle or a pistol, a short burst from a sub-machine gun, or even rounds from a suppressed weapon. In the pit the instructor would point out the different sounds that were heard by the people in the pits. A suppressed MP5SD was subsonic downrange and made a whirring sound as it went by. There was no report from the gun, yet with time students could tell the direction that the shots came from. The same thing was done at night. The result was that by the end of the exercise students could identify the type of weapon the round was fired from, the distance to that target, and the direction the shots came from. Eventually we progressed this exercise to an unknown distance range with heavy woods and open areas. The students were on the ground downrange and shots were fired over and past their side with the same weapons. This was a tremendously valuable exercise for locating an enemy position. They were allowed to see the muzzle flash and then the crack of the bullet, followed by the thump of the weapons system used. Seeing a .50-caliber rifle fire at you at night is a very disturbing thing. It's downright scary.

This is an easy exercise to set up in an open area. Of course, experienced operators should be behind the weapons. We used 25-30 different weapons systems. Use what you have available and if it's only a sniper rifle, the training gained is invaluable.

METHODS AND ANALYSIS OF RANGE DETERMINATION

Range determination for the distances used in Hard-Target Interdiction and extreme range shooting present some very tough challenges. Snipers and operators have developed different methods and techniques over the years to try and narrow their margin of error in determining that range. Earlier we used a danger space table to show to what degree of accuracy our range determination must be. We have discussed the visual means of range estimation and now we are going to discuss the mechanical means of range determination. We will also analyze some of the traditional methods of determining the range to the target and identify their weaknesses and



M-19 Binocular Reticle Pattern

strengths. We will examine some of the common errors in this method and further examine the use of danger space to back up our findings.

Different mechanical means are always used to get a range to the target. We are going to present how to use the standard means and we will discuss a couple of methods that I don't think you have heard of before. Way back in the beginning of this book, I said that this stuff was cutting edge. One of the methods in this chapter is the hot air in front of that cutting edge. Yet it uses a formula that is as old as time. At this point it is necessary to examine the different pieces of equipment that are used in determining the range. Some of these you are familiar with and some you are not. One piece, the telescopic sight (and I'm NOT talking about a Mil Dot reticle) is used to determine range to a very fine level. Sniper teams have at their disposal a varying degree of optical systems to determine the range to the target. So with that, let's jump in neck deep.

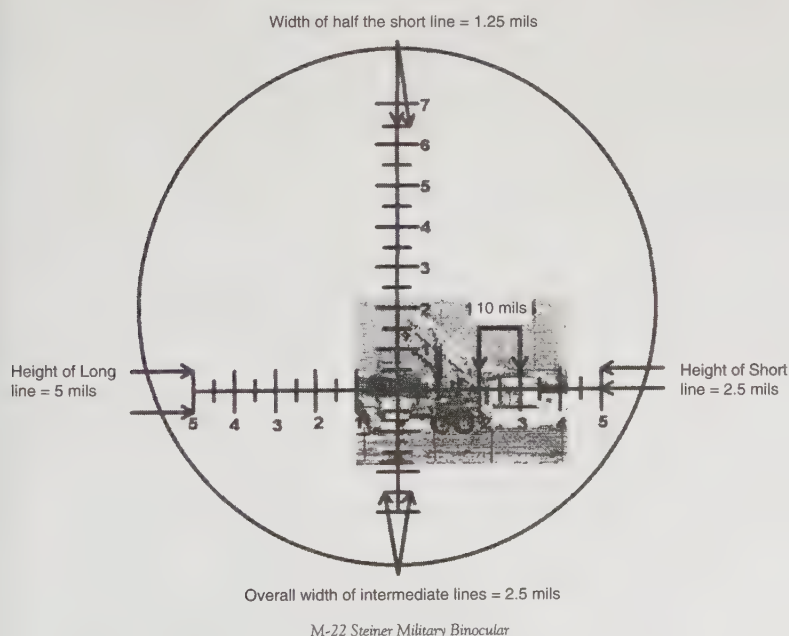
The M-19 Binocular

The M-19 binocular has been around for a long time. It has been and still is a favorite among the snipers out there. It has been or is being replaced by the M-22 Steiner binoculars. There are problems with the M-22, however, and the M-19 is still the favorite. The photo of the M-19 explains the reticle pattern. These binoculars are 7X only. They have excellent optical properties but are of very low power. Field artillery observers have long used this binocular for range determination and for correcting the shot of the gun for indirect fire.

The M-22 Binocular

The M-22 is the newest addition to military binoculars. The Steiner is a fine binocular. The mil scale is a little bit more advanced than the reticle on the M-19 binocular. All of the dimensions remain the same with the exception of the additional vertical and horizontal cross lines that intersect the main crosshair. These short lines are a total length of 2.50 mils long. That splits in half to a value of 1.25 mils above and below the main crosshair. These binoculars are rubber armored but they have one major shortfall. They have a laser protective coating that is designed to keep battlefield lasers from burning the eyes of the soldier using these binoculars. This coating is like a bright headlight that shows up immediately downrange. Some operators have removed the outer lens covers that house these protective lenses. This is probably OK for some operational environments but there is a very good reason for the laser protective coating. There have

been proposals that high value targets use pulse lasers to defeat direct visual observation. A program on the Discovery Channel once aired an interview with some pilots that were victims of laser attack. They talked of sudden blindness or severely limited vision as a result of the laser attack. These individuals had no idea what had happened to them or that they had been attacked. It may be a good idea for sniper teams to have their own laser detector system (counter-countermeasures). The electronic battle goes on. The M-22s are a bit more bulky and some say the optics are not as clear as the M-19s even without the protective coated lenses. Something else, the M3A optics also have a laser protected filter that screws into the objective lens end of the day scope. But what about the night time?

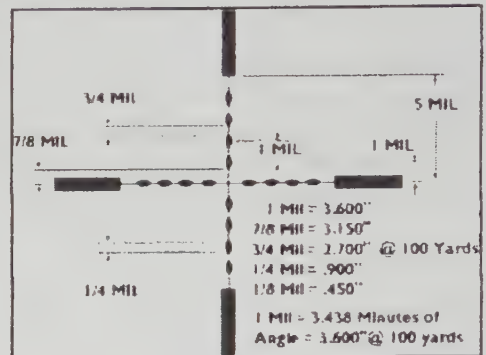


The Mil Dot Reticle Pattern and other Ranging Reticle Patterns

This reticle pattern is probably the most proliferated reticle pattern in use around the world for sniper grade optics. This pattern is the basis for the mil relation formula that has grown to be the most popular method of range finding out there. But there are severe limitations with mil relation theory. (Actually, it's in the execution of that theory.) In theory, the mil relation method is fantastic. But that's in a perfect world where the target stands still and doesn't move for the shooter. And he doesn't do this for 10-15 seconds. It also assumes that the conditions are such that the edges of the target appear clear enough for the shooter to identify them. The light conditions have a lot to do with this. When the light is behind the target, you will determine LONG even giving a non-moving target. This is for the same reasons as above.

SPECIAL NOTES ABOUT THE MIL DOT RETICLE PATTERN

- The most common mistake made when using the reticle is the location of the ¼ MIL setting. Many operators assume the inside edge of the MIL dot to be the value of ¼ MIL. Mathematically, the value of the edge of the MIL dot is .1111 MILS. ¼ divide by 2 = .375 divide by 3.375 = .1111 MILS.
- Not all MIL dots are the same. There is optics out there with oval shaped dots. You must go to the manufacturer of the scope to get the dimensional values of these dots.



While this book is on Hard-Target Interdiction, part of that is extreme range shooting. HTI operators that are engaging a hard target may have the opportunity to engage personnel targets of high value (although politically this probably would require real world approval from the command). I realize that some of this is negative information in that it attacks a long-used method of range determination. However, this does not work at the ranges used in HTI missions. The reality is that for most military sniping ranges, mil relation is something of a parlor trick. For light class shooters, there are techniques that are covered later in this book that eliminate the need for determining the range to about 650 meters. Past this range, mil relation isn't good enough. At this point, it's time to discuss the mil relation formula and its use. While I have thoroughly slammed this method, it still does have its uses and for certain Hard-Target Interdiction missions. Mil relations do work because the targets are huge and they are NOT moving. Unfortunately, personnel targets are neither.

$$\text{Range to target} = \frac{\text{Size of object (meters or yards)} \times 1,000}{\text{Size of the object in mils}}$$

If the size of the object is entered in yards, result is in yards; if entered in meters, the result is in meters.

$$\begin{aligned} \text{EXAMPLE: } 6\text{-foot man} &= 1.83 \text{ meters} \times 1,000 \\ &= 2.5 \text{ mils} \\ &= 732 \text{ meters} \end{aligned}$$

$$\begin{aligned} \text{EXAMPLE: } 6\text{-foot man} &= 2 \text{ yards} \times 1,000 \\ &= 2.5 \text{ mils} \\ &= 800 \text{ yards} \end{aligned}$$

Note the difference when yards are used versus meters. The Army is using meters and has been for a while.

The Navy operators use yards. Don't assume that yards and meters are close enough to be the same—they are not. At 1,000 meters, the equivalent value in yards is 1,094 yards. That's a 10 percent difference in the range.

The Mil Dot reticle is a method for determining the angular size value of a target of known size or height. Note that I said "known size or height." Each and every human target that an operator will have to mil is going to have to have a height value assigned to that target height. Now, some out there may think that operators have this folder that tells them the size of their target. Uh-uh, not likely. Maybe in a narrowly focused sniper community, but not generally. So the sniper team must estimate the size of their human target. Let's examine the effect of such estimation and the error that is induced. Remember danger space? Here's where it rears its ugly head again.

EXAMPLE RANGING PROBLEM

Analysis of difference in range when a target height is 6" shorter than the actual height of the target.

Target Estimated at 6'0" = 1.83 meters X 1000 = 1830 divide by 2.5 MILS = 732 Meters

Target Actual Height 5'6" = 1.67 meters X 1000 = 1676.4 divide by 2.5 MILS = 670.56 Meters

Difference of 61.438 Meters due to 6" target size error. Danger Space for 670 meters = 28 meter bracket. For center of impact aim, DS is 14 meters in front and behind the target.

If the operator dialed "7" on the M3A scope for 700 meters, the shot would travel 20" above the point of aim. If the point of aim were at the heart, this shot would be about 5" over the top of the targets head due to a 6" error in estimating the height of the target.

NOTE: This does NOT take into account errors in determining the value of MILS when obtaining the height of the target in the MIL scale. This error is easier and more significant.

Using mil relation and the Mil Dot reticle presents another problem for shooters using the Mil Dot reticle for determining the range to the target. This problem is when determining exactly how many mils tall a particular target is. In TC 31-20-4, on page 53, a paragraph states that a mil estimation must be within 1/2 mil to be within the allowable 10 percent error allowed on tests at SOTIC. This 1/2 mil error may be acceptable for tests there, but it's totally unacceptable for real-world applications when bounced off of, you guessed it, danger space tables. Let's examine the effects of a 1/2-mil error. We are using the M118 cartridge data tables because information sources on common range estimation methods abound. The ranges examined are all well under the published maximum effective range of the M-24 SWS with M118 ammunition.

DANGER SPACE - 20 INCH KILL ZONE M118SB

RANGE	35 IN.	55 IN.	2 MOA
100 M	POINT BLANK ZERO		114 M
200 M	POINT BLANK ZERO		77 M
300 M	320 M	1034 M	62 M
400 M	178 M	510 M	54 M
500 M	105 M	274 M	44 M
600 M	73 M	179 M	38 M
700 M	50 M	118 M	31 M
800 M	37 M	85 M	26 M
900 M	27 M	63 M	22 M
1000 M	21 M	48 M	19 M

Now we are going to apply the same mil relation theory to the possibility of ranging hard targets of a large size at the operational ranges that Hard-Target Interdiction missions are conducted. The large size of these targets makes it a bit easier for operators to see the defined edges of these targets. These targets also usually are not moving, but if they are, there are other solutions for this problem. Mil relation CAN work in HTI missions, but the operator must bounce the error possibilities off their danger space tables to understand these errors. Optical sights that are on the heavy rifles are

EXAMPLE RANGING PROBLEM / EFFECT OF MIL INTERPOLATION ERROR

USING ALLOWABLE ½ MIL ERROR IN TC 31-20-4

MIL Reading @ 2.5 Mils = 1.83 meters X 1000 = 1830 divide by 2.5 MILS = 732 Meters

MIL Reading @ 3.0 Mils = 1.83 meters X 1000 = 1830 divide by 3.0 MILS = 610 Meters

ERROR = 122 Meters. This is even outside of a 55" vertical target!!! DS = 31 Meters. If true range were 732 meters and operator estimated at 610 meters with a ½ MIL error, round would land 122 meters short!

ERROR OF ONLY ¼ MIL INTERPOLATION

MIL Reading @ 2.5 Mils = 1.83 meters X 1000 = 1830 divide by 2.5 Mils = 732 Meters

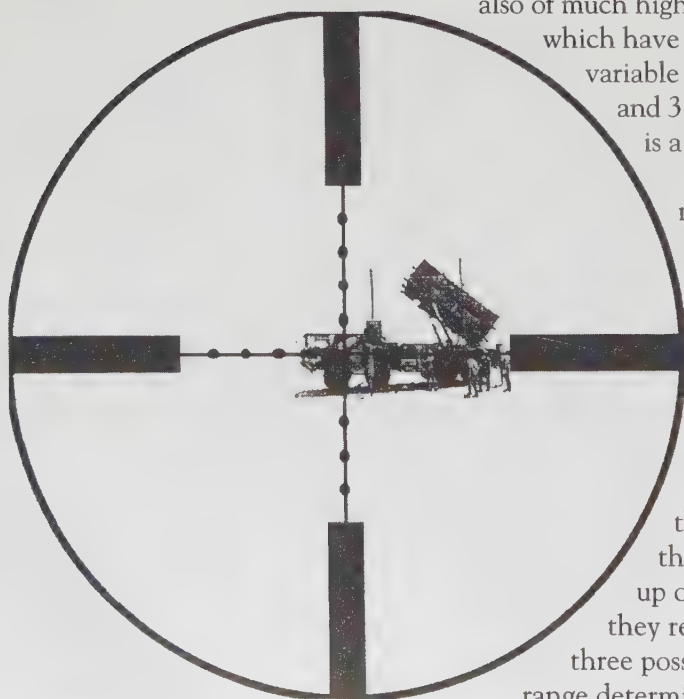
MIL Reading @ 2.75 Mils = 1.83 meters X 1000 = 1830 divide by 2.75 Mils = 665 Meters

ERROR OF ONLY 1/10th MIL INTERPOLATION

MIL Reading @ 2.5 Mils = 1.83 meters X 1000 = 1830 divide by 2.5 Mils = 732 Meters

MIL Reading @ 2.6 Mils = 1.83 meters X 1000 = 1830 divide by 2.6 Mils = 704 Meters

Even at this small 1/10th Mil error the error in range is 28 meters. This may not sound like much but it is the difference between a killing shot and a potential miss between the legs or a miss off of the side of the head due to a wind change.



also of much higher power. Operators have the U.S. Optics scopes, which have a greater mil relation capability. With the very high variable power capabilities of these scopes (SN-3 @ 3.2 to 17X and 3.8 to 22X) and their high resolution lenses mil relation is a very strong possibility.

This does not solve all of the problems with using mil relation for HTI missions. The operators may be in an area where the specified target has not arrived yet. This means that the operators will not have time to get the range and make the MET and ENV conditions corrections. There are solutions for these problems, but first let's examine some of the different errors and their impact on determining the actual range to the target. We will also explore another error that can occur at long ranges. That is the effect of slant angle on the visual appearance of the target. When looking at tall vertical targets on an up or down angle, these targets will appear smaller than they really are because of the angle. We will examine the three possible errors that can be made with MIL relation in range determination.

EXAMPLE RANGING PROBLEM / EFFECT OF TARGET HEIGHT ERROR

Target Height @ 11 Meters = $11 \times 1000 = 11,000$ divide by 7 Mils = 1571 Meters
 Target Height @ 11.5 Meters = $11 \times 1000 = 11,000$ divide by 7 Mils = 1642 Meters

Error = 71 meters.

What is the effect? On a target of 11 meters that can sustain a hit anywhere, the bullet will still strike the target. Danger Space at 1600 meters = 247 meters for a 11 meter tall target. If the critical component must be attacked that is only 3 meters high, there is potential for a miss with a Danger Space of only 61 meters for Mark 211, Mod-0 ammunition.

EXAMPLE RANGING PROBLEM / EFFECT OF MIL INTERPOLATION ERROR

Refer to the Danger Space Table on P. 4 of this chapter.

USING ALLOWABLE ½ MIL ERROR IN TC 31-20-4

MIL Reading @ 3.5 Mils = 5 meters X 1000 = 5000 divide by 3.5 MILS = 1429 Meters
 MIL Reading @ 3.0 Mils = 5 meters X 1000 = 5000 divide by 3.0 MILS = 1667 Meters

ERROR = 238 Meters split in half for a center aim (119 meters in front of and behind the target). This is outside the parameters for an 5 meter target (125 meter DS, split in half = 62.5 meters in front and behind the target). This is a miss on the overall target. The key number is the split. If the range error split is larger than the DS split, a can will occur, long or short.

ERROR OF ONLY ¼ MIL INTERPOLATION

MIL Reading @ 3.0 Mils = 5 meters X 1000 = 5000 divide by 3.0 MILS = 1667 Meters
 MIL Reading @ 3.25 Mils = 5 meters X 1000 = 5000 divide by 3.25 MILS = 1538 Meters

ERROR = 129 Meters split in half for a center aim (64.5 meters in front of and behind the target). This is outside the parameters for a 5 meter target (125 meter DS, split in half = 62.5 meters in front and behind the target). A miss can occur with only a ¼ Mil error.

ERROR OF ONLY 1/10th MIL INTERPOLATION

MIL Reading @ 3.0 Mils = 5 meters X 1000 = 5000 divide by 3.0 MILS = 1667 Meters
 MIL Reading @ 3.1 Mils = 5 meters X 1000 = 5000 divide by 3.25 MILS = 1613 Meters

ERROR = 54 Meters split in half for a center aim (27 meters in front of and behind the target). This is within parameters for an 5 meter target (125 meter DS, split in half = 62.5 meters in front and behind the target). This small error is okay to hit a target 5 meters high.

Now that I've beaten this concept and theory up, this is how it works. Here's the formula once again:

$$\text{Range to Target} = \frac{\text{Size of object (meters or yards)} \times 1,000}{\text{Size of the object in mils}}$$

Here in the United States we are not used to seeing things in how many meters or yards high they are. We are used to inches, or feet and inches. The first step is to convert the height of the target to either yards or to meters.

STEP 1: 5 feet 6 inches = 66 inches divided by 36 (inches per yard) = 1.8333 yards tall
 5 feet 6 inches = 66 inches divided by 39.37 = 1.6765 meters tall

STEP 2: $\frac{1.6765 \times 1,000 \text{ (inches per meter)}}{2.5 \text{ mils}} = 1676.5$

STEP 3: 1676.5 divide by 2.5 = 670.6 meters to target

There are some standard measurements that are pretty accurate to aid a military sniper use this range estimation method. These include some standard sizes of human anatomy and some sizes of equipment.

- The average human being is 1 meter from the top of his head to his crotch.
- The average human being is 20 inches across his shoulders.
- The average human head is 10 inches tall from the top of the head to the chin.
- The distance from the ground to the deck of a Soviet tank is approximately 1 meter.
- The distance from the top deck to the top of the turret is approximately 1 meter.
- The average height of a U.S.-made sedan is about 4 feet from the ground to the top of the roof. (This must be checked for certain vehicles as cars become more and more different in design and specification.
- Operators in an urban environment can get good data off the doors in their area for door height and width. Windows are out of the formula, as they are too different to rely on.

We have established the value of the mil relation formula and I have presented some weaknesses. Personally, I have little faith in the ability of an operator to range his human target using this method. At SOTIC, the average class was 20 shooters. As part of the range-finding class, they were taught the mil relation formula. Some of the Rangers and regular infantry shooters that were trained at Fort Benning thought they had a leg up on the others until we hit the field exercise phase. At first, they executed the mil relation formula on E-shaped silhouettes that are 1 meter tall. They were allowed 5 percent error in their range. They were given 1 minute per target to do the mil estimation and calculate their range.

I then sent an instructor downrange with a radio until I instructed him to stop. The other instructor and I had worked out what his actions were going to be. All the shooters were behind their guns with instructions to begin their ranging and all they were allowed to do was obtain a mil reading. They would do the math later. I had the instructor do the following five actions downrange and on command the shooters had 10 seconds to obtain the mil reading (more than real-time by far).

1. The instructor walked directly across the front of the shooters at a crouched ready, patrol pace doing point man stuff. He stopped, stooped, crouched, turned around, looked up and down and did other things a point man would do. He even backed up, did a lateral shift and then proceeded forward. Totally unpredictable. First mil reading.
2. The instructor came to a sudden halt and froze for about 3 seconds then took a knee. He was about 500 meters away at this point. The instructor looked all around and then took a prone position on the ground. Second mil reading.
3. The instructor took an entrenching tool out of his rucksack and begin digging a hasty fighting position. He did this for about 1 minute. Third mil reading.
4. The instructor was acting as part of a larger patrol that was establishing a rest over night (RON) position. The instructor then stood up, walked about 15 meters where he relieved himself against a tree and then returned to his prone position on the ground. Fourth mil reading.
5. The instructor stood up with his weapon and begin running at a dead run for about 40 meters, where he disappeared into a gully. Fifth mil reading.

The point of this exercise was to show the students just how difficult it is to obtain the range using the mil relation method. The target never varied in range more than a 50 meter bracket. Some of the students caught onto the fact that he never really moved in or out. A couple did and used that point to take multiple readings as fast and as often as possible. The smart operators then averaged their readings. They were allowed to use any part of the anatomy or any piece of equipment that was standing there while this was going on. The mil readings ranged from 1 mil to 4 mils. They were ranging on all types of objects. The only size that they were sure of was the 39-inch frame from the top of the target's head to his crotch, but because of the target's activity, obtaining a clear picture of this target frame was impossible. The shooters went on guesses.

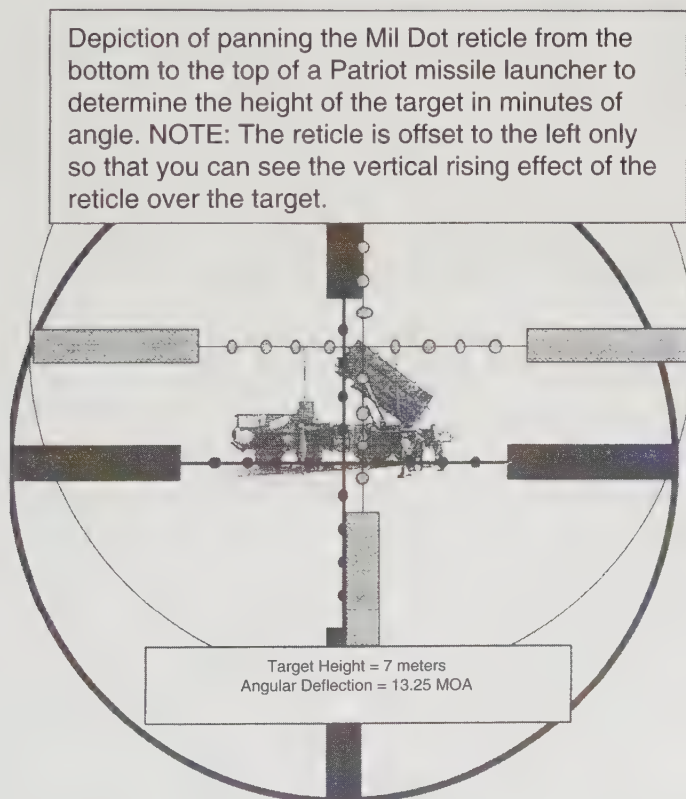
The ranges varied from 230 meters to 760 meters, yet the range never varied more than 50 meters (when the operator ran away and disappeared). I pretended to be pissed off at their inability to range the target. One guy was quietly working on the side—he never got behind his rifle the whole time. He just sat there and watched. Their major complaint? The target wouldn't sit still long enough to be ranged. The loudest complainers were the guys who had previous training and expected to see stationary E-shaped silhouettes downrange.

I started laughing and had the instructor walk up to his original position and assume the position of attention. I then allowed the shooters to get behind the guns and mil the target. They were still off. Why? The target was now wearing a ghillie suit and his background about 40 meters away was thick scrub oak. They couldn't clearly define the edges of his silhouette to get an accurate reading. These guys were getting pissed. All except the loner sitting there quietly. I knew what he was up to and he seemed confident. He had already been in a couple of our courses also. That helped. He gave a class on light conditions, nature of the terrain, and the nature of his target and stated the range to be 500 meters with a running range of about 25 meters.

There was a lot of silence in the group after that. The mil relation theory with that group just died a mean death. We then stepped into the world of advanced range determination. We used an instrument that they all had on the guns already (the M3A or the M1A scope) and another instrument called the theodolite. This they had never seen before. This next method is something new and it also adds another correction to our calculations.

RANGE DETERMINATION BY ANGULAR RELATION

Angular relation is a method to measure the height of an object by using your optical sight or a theodolite. In principle, this is the same as mil relation. The difference is that you manipulate a sight or a theodolite and pan your reticle from the bottom of the target to the top. However, it requires that the target be stationary in nature longer than the Mil Dot method. This is of great use against material targets and increases your range-



finding resolution. To use this method the sniper must bag his gun under the rear of the rifle and settle the gun well into the bag. The gun must be steady enough so that the sniper can manipulate the elevation knob without disturbing the lay of the gun. This method works better when using the M1A because of its 1/4 MOA settings versus the full MOA settings on the M3A. Here are the steps:

1. Carefully bag the toe of the gun and lay the gun on the target. The reticle of the scope does not necessarily have to be dead center over the target. It can offset left or right as much as the operator wants.
2. Turn the elevation knob up or down so that the horizontal crosshair or any horizontal point of reference you wish is at the bottom of the target. Note the value of this setting on the elevation knob.
3. Turn the elevation knob up while looking through the scope at the target. When that horizontal point of reference reaches the top of the target, stop. As you turn, count the clicks that you move the knob.
4. If you were using a BDC scope with 1 MOA clicks, in the above example you would have a 13 minute or click movement. If you are using a 1/4 minute scope, you will have moved the knob 53 clicks.
5. This method uses the same formula that you use when doing mil relation using the Mil Dot reticle. You must convert your clicks or minutes of angle to mils before you can run the formula. Use the following formula:

Minutes of Angle divided by 3.375 = mils

6. Execute the mil relation formula using the data obtained from this method:

13.25 converted to mils = 3.92593 mils

7 meters X 1,000 = 7000

3.292593 mils

=1,783 meters to target

Now we will study what the effect of a deflection calculation error on the range to the target. This is bounced off of the danger space table for that cartridge.

EFFECT OF A DEFLECTION ERROR ON THE RANGE TO TARGET

Effect of a 1 Minute of Angle Error / Correct Measurement = 13.00 MOA or 3.85185 MILS

Danger Space for a 7 meter target @ 1800 meters = 111 meters

- **13 MOA deflection = 1817.30769 Meters REAL WORLD RANGE**
- **12 MOA deflection = 1968.75000 Meters / Outside Danger Space Specification**
- **14 MOA deflection = 1687.50000 Meters / Outside Danger Space Specification**

Effect of a ½ Minute of Angle Error

- **13 MOA deflection = 1817.30769 Meters REAL WORLD RANGE**
- **12.5 MOA deflection = 1890.00000 Meters / Within Danger Space Specification**
- **13.5 MOA deflection = 1750.00000 Meters / Within Danger Space Specification**

Effect of a ¼ Minute of Angle Error

- **13 MOA deflection = 1817.30769 Meters REAL WORLD RANGE**
- **12.75 MOA deflection = 1852.94118 Meters / Within Danger Space Specification**
- **13.25 MOA deflection = 1783.01887 Meters / Within Danger Space Specification**

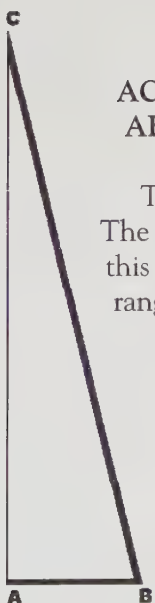
This method may seem like a rehash of the mil relation method that I wasn't too fond of earlier. I don't have a problem with mil relation. I only have a problem in applying that against human targets that don't seem to sit still too long. Using that method against stationary targets is great as long as the shooters are aware of the problems caused by miss-estimating the height of the target and missing the mil error on the scope. Using the angular relation method allows the shooter to use the finer angle resolving power of the M3A or 1/4 MOA capable scopes. These are powerful instruments. The finer resolution of high power optics like U.S. Optics allows the shooter to see edges of targets that don't have good contrast on them. These are conditions that other optics cannot live up to, and those low contrast edges become impossible to define.

DETERMINING RANGE TO TARGET USING TRIANGULATION AND ANGULAR RELATION

We are now at the pinnacle of range-finding operations. Many times a sniper team may arrive in an operational environment where the target has not yet arrived. Indeed, in many special operations situations, unless the target is materiel and anchored to the earth, the team will try to arrive long before the target arrives. This allows them to set up the shot on their terms instead of the enemy's terms. They can set up the shot along the dominant wind line and thereby reduce their crosswind problems. They can also set up the shot so that the sun is behind the sniper team and reduce the target's security apparatus ability to identify and located the sniper team.

Triangulation is a method that uses a baseline at the sniper's position and a compass or other angle-measuring device (M-2 compasses work better than the military lensetic). This method works best when using two operators, although one man can do the job. Triangulation measures the angular difference from a line that goes from the gun to the target and a line from a point 90 degrees to that line but between 20 and 50 meters to the right or left of that gun. To do this formula you need a scientific calculator. As mentioned way back in Chapter 2, I recommend the Hewlett Packard HP-20S. The appendix to this book contains a program sequence for programming this formula into a HP-20S. The key that is important here is the SIN key. This is an extremely accurate method of range determination. Its main use prior to target arrival is setting up a highly detailed range card. Here is the formula:

$$\text{Range to Target (Line AC)} = \frac{(AB) \times \text{SIN of angle B}}{\text{SIN of angle C}}$$



AC = is the gun to target line.

AB = is the baseline cord length or in the later application, the size of the target.

The baseline cord length has an important impact on the accuracy of the range determination. The larger the baseline when using a compass, the more the accurate the ranging. A GPS makes this process easier. The following cord lengths are based on experience. The operators take a visual range estimation and base their cord length on this estimation.

- 0-400 Meters = 10-meter cord length
- 400-600 Meters = 20-meter cord length
- 600-700 Meters = 30-meter cord length
- 700-Infinity = 40 or more cord length

An HTI sniper team moves into an area looking for an FFP. They will return to their objective rally point after they obtain some visual target reference points (TRP). Before the

team lies a major road intersection but there is nothing in that intersection that gives them anything to determine a range using angular deflection or mil relation. The team leader directs one of the team members to pull out a roll of "low stretch" cord that is knotted every 5 meters. They are going to execute a triangulation to the intersection that they can build a range card on. At this point they are only gathering minimal data so they can complete their calculations later. The members take a look at the situation and visually estimate a range (and some map use) of about 1,400 meters to the intersection.



HTI operators laying a baseline.

1. One of the shooters pulls out a compass and a stake that he prepared earlier at the ORP. He drives this stick in the ground at the proposed gun position. He lays his compass on the top of the stake and notes the azimuth to the target. In this case he gets an azimuth of 320 degrees magnetic (5,688 mils). This establishes line AC.
2. Now he needs to establish the line AB. By adding 90 degrees to the compass setting he gets a desired azimuth of 50 degrees magnetic (888 mils) azimuth. He turns the compass until 50 degrees falls under the indicator line on the compass face. This establishes the AB line angle.
3. Another team members starts at the gun position and runs the cord along this 50 degree line. He stays online by directions given him by the compass man. He has determined that due to the terrain and situation a 50-meter baseline cord be used. As he reaches the 50-meter measurement, the compass man gives him a final correction to keep him online as he drives a stake at the Point B of the AB cord.
4. The compass man then moves to Point B where he lays his compass on the stake. He takes an azimuth to the intersection and notes this azimuth. A better method is for one man to line up the compass and a second man takes the reading off the compass face. He gets a direct magnetic reading of 318 degrees magnetic (5,653 mils). This is a deflection of 2 degrees.



Compass man laying the AC line.

NOTE: A half-degree error in this method results in a difference of 130 meters in the range to the target. An M-2 compass works better because of its finer resolving ability using mils over degrees.

5. The recon team moves back to the ORP to finish their calculations and finalize their plans. In the ORP, the compass man begins his calculations to get the range to the target. Here are the specifics:

AB = 50 meters

Angle B = 88 degrees / SIN = .99939

Angle C = 2 degrees / SIN = .03490

$$AC = \frac{(50) \times \sin B (.99939)}{\sin C (.03490)}$$

$$AC = \frac{49.96950}{.03490}$$

AC = 1431.790 meters from gun to intersection / initial elevation setting of 71.00 MOA for Mark 211, Mod-0 under standard atmospheric conditions.

6. At the team leader's convenience the shooters can place preliminary elevation data on their gun as the team leader gathers MET and ENV conditions in the target area. Operators can be further dispatched to take wind readings in the area. It is NOT recommended that operators go down into the target area and disturb that area. You never know what security apparatus may move into the area before your shot.

Some tricks can aid the compass man in laying in the AC and AB lines. With the naked compass, it is tough to get an accurate reading. Here are some tricks of the trade.

- Use a Silva compass mounted to a small wooden or plastic board. The compass is mounted exactly parallel along a centerline in the board. A low power optical sight such as the ACOG from an M-4 system is mounted in front of the board and acts as a precision aiming system for the compass. Have the two about a foot apart so you don't get magnetic influence from metal in the ACOG scope. This method gets you very tight on the azimuth to the target. The wire in the lensetic compass sight is thick enough to cover a target at 1,500 meters.
- Binoculars with a compass built into them. Steiner and Leica both offer binoculars with compasses built into them. This also gives you a magnified image of the target as well as the crosshair in the binocular to use as an aiming point at the target area.
- As stated before, the longer the AB cord, the more accurate the reading will be. It is possible to use a GPS to get an exact fix of your location at the gun. The compass man then takes a reading to the target. While this is going on, another recon element moves to a terrain feature that on the map is 300 meters to the right. When they are in position on the hill, one of them displays a small orange panel that the compass man uses to get them on the required 90-degree angle to the gun-target line. The second team takes a GPS fix and they take a compass reading to the target. By subtracting the coordinates from each other, they can determine exactly how many meters the two teams are apart. This is the AB line. The Angle C will be much much larger thereby making the range that much more accurate.

$$\begin{aligned} AB &= 331 \text{ Meters after GPS fix} \\ \text{Angle B} &= 77 \text{ degrees magnetic} / .97437 \\ \text{Angle C} &= 13 \text{ degrees magnetic} / .22495 \end{aligned}$$

$$AC = \frac{(331) \times .97437}{.22495}$$

$$AC = 1433.725 \text{ meters}$$

As with many of the techniques in this book, these methods are intended to be a jog of the brain as much as locked in cement. Other operators may and will come up with different methods for obtaining an accurate AB cord length. This method requires a good deal of practice in order to prove its worth and for the operators to have faith in its ability. Precise use of the compass and other supporting equipment is of utmost importance.

When using the GPS use the averaging mode on it to get a super-accurate fix on the location of the gun and the Point B.

To gain an even more accurate range to the target, use multiple methods and repeat your measurements several times. If they vary a little from measurement to measurement, average the measurements out. Of course, another method (albeit a dangerous one) is to walk out to the target area with the GPS and get a super-accurate averaged fix on the target location. Subtract the two coordinates and you have your range to target.

ANGULAR DEFLECTION WITH A THEODOLITE

At Fort Bragg not long after I started finishing the first sets of .50-caliber tables I was very interested in solving another problem that we were having—solving the range determination problem to a super fine level. Long before I was in the Special Forces, I was in the conventional army as a combat engineer. A few times, we were on road construction projects in some of the major training areas in Europe. I remembered that there were a couple of engineering officers that had used a mechanical theodolite to lay out the road sites. One of these officers explained a little about the capabilities of these instruments and how they resolve and measure angles to a very fine degree, much better than standard engineer transits.

Triangulation was taught at SOTIC when I first attended the school. Somewhere while investigating range determining possibilities and trying to refine the methods of triangulation, I remembered theodolites and their capability. I called one of the surveying companies in Fayetteville, NC, and arranged some time with the owner. A trip downtown and some time with the owner of the store confirmed that I could indeed measure the size of an object in seconds of arc or minutes of angle. Remember earlier in the chapter when we covered mil relation and the Mil Dot reticle? There is a potential for huge error at long ranges because of the low power of the telescopic sights and the strong possibility of the operator messing up the mil value for a target.

We then talked about using the telescopic sight elevation drum for determining the angular deflection of a target. The single MOA or the 1/4 MOA capability of measuring the target height made for a huge jump in the precision capability in finding the range to the target. Triangulation using a compass and a baseline expanded our range-finding capability but when using a magnetic compass this method has the potential for huge error when using a small baseline. The large baseline option meant a lot of moving around for a sniper team, which isn't good site security for the team.

Now we are going into the world of theodolite range finding. This is by far the most state of the art, precise method of determining a range to a target. A theodolite is a precision instrument that costs about \$4,000.00. That may sound like a lot of money, but consider what the theodolite can do. Here are some of the advantages of the theodolite.

- Replaces two instruments with one: the spotting scope and a laser range finder or other range-finding gear. In replacing two instruments with one, you save maintenance money and the theodolite is cheaper than military grade laser range finders.
- Ultra high resolution and high power (24X typically) optics make for an excellent spotting scope as well as a range-finding instrument.



HTI operator training up a theodolite.

- System is totally passive. There is no laser to shoot downrange and risk detection.
- Night vision systems can be easily adapted to the objective lens assembly or the ocular lens assemblies. A laser pointer can be slaved to the theodolite for designating targets at night when necessary.
- System can be used on a target that is stationary or an object close to the target that is very small. This depends on the resolving power of the theodolite. A common system available in the military or outside is a 6-inch theodolite (6 inch is explained in a little bit).
- This method can also be used like the baseline and compass method by moving the theodolite from Point A to Point B and then measuring Angle B instead of Angle C.

We have used all kinds of units of measure for anything for windage holdoffs, mil relation, and holdovers high and low (mils). We have also used another unit of measure that is used for elevation and windage (MOA). Theodolite range-finding uses another unit of measure that is finer than mils or minutes. These are seconds of arc. A second of arc is 1/60th of a MOA. That is a mighty small angle. Theodolites can read angles to 1 inch of arc. The more common ones read to 6 inch of arch. The following units of measure subtend as follows:

$$\begin{aligned} 1 \text{ mil @ } 1,000 \text{ meters} &= 39.37 \text{ inches} \\ 1 \text{ MOA @ } 1,000 \text{ meters} &= 11.38 \text{ inches} \\ 1 \text{ second of arc @ } 1,000 \text{ meters} &= .18967 \text{ inches} \end{aligned}$$

The first theodolite that I was able to obtain for testing I actually borrowed from the Civil Engineering section responsible for property maintenance at Fort Bragg, NC. Thanks for the use of that instrument, guys.



Author with theodolite, Yakima, 1996.

When I took that instrument back to my place of work I immediately took it out and mounted it on the tripod. I had not had any formal training in the use of this instrument. After playing with the knobs and reading the book that came with it, I had a rough idea how it worked. I knew that the theory was sound because of mil relation theory and using the Leupold & Stevens M1A scopes to measure the height of a target in 1/4 MOA clicks.

The first thing that I did was work out some of the problems on paper and determine the degree of accuracy that I could expect using this method. The theodolite that I borrowed was a Wild T-6 with a 6-inch resolution capability (meaning it could give you a reading from the optical micrometer in 6-inch increments). Here are some of the results of that initial paper testing.

Value of Units of Measure at 10,000 Meters

- 1 mil @ 10,000 meters = 393 inches
- 1 MOA @ 10,000 meters = 113.8 inches
- 1 second of arc @ 10,000 meters = 1.883 inches
- 6 seconds of arc @ 10,000 meters = 11.30 inches

Resolving Power of Different Instruments Used for Triangulation

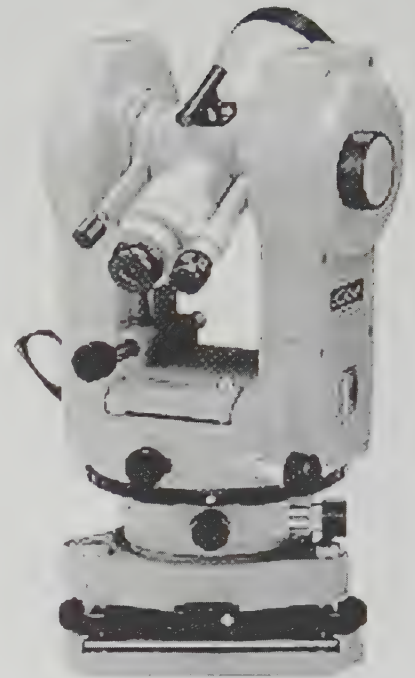
- The standard military compass can with great skill and practice (on a sighting board) resolve to .5 degrees with visual interpolation (usually a second person taking the reading).
- The M2 compass that reads in mils can resolve a 2 mils reading off the compass.
- The average theodolite can resolve to 6 inches of arc. Models are available that resolve typically to 1 MOA, 20, 10, 6 and 1 second of arc.

Examples of Error at Different Ranges with Three Different Instruments

- Using a compass: True range = 1,572 meters. Baseline = 40 meters. A half degree error in compass reading may result in a – or + 427 meter error.
- Using an M2 compass. True range = 1,629 meters. Baseline = 40 meters. A 2 mil error in compass reading may result in a – or + 120 meter error.
- Using a 6 inch theodolite. True range = 1,712 meters. Baseline = 40 meters. An error of 18 seconds of arc (3 times the capability of the sight) = 6.4 meter error.

Each theodolite operates the same way. To go into the operation of each knob on each type of theodolite would add many more pages to this book. A major advantage of the theodolite is that it reads both horizontal and vertical angles. This not only gives the operator the vertical or horizontal angular deflection of the target, but it also gives the up or down angle to that target. These instruments have two types of scales that you take your reading from. The first is a vernier scale. These take some tricky reading experience from the operator. If you have ever worked the scale on the iron sight of the M-24, this is that system on steroids. In fact, it's probably not workable under field sniper conditions.

The best type of scale is the optical scale. There is another small scope next to the main tube. Inside of this scope is nothing but a scale reading. There are many types of scale readings. Some of these are listed below:



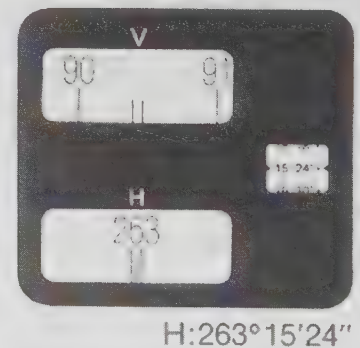
Optical micrometer along the side of the main tube of the theodolite.



Example of a 1 Minute theodolite, with a capability to interpolate to 30 seconds.



Example of a direct reading 1 Second theodolite, Horizontal reading only.



Example of a Direct Reading 6 second theodolite. Combination vertical and horizontal

There are two methods for determining the range using a theodolite.

METHOD 1. Determining range to a target not at the target site. This method is used when the target is expected in the target area, but has not yet arrived. With this method, the operator must move the theodolite. This lowers the precision of the range determination. Using a large baseline when possible makes up for a lot of this error. Baseline recommendation is 30 meters.

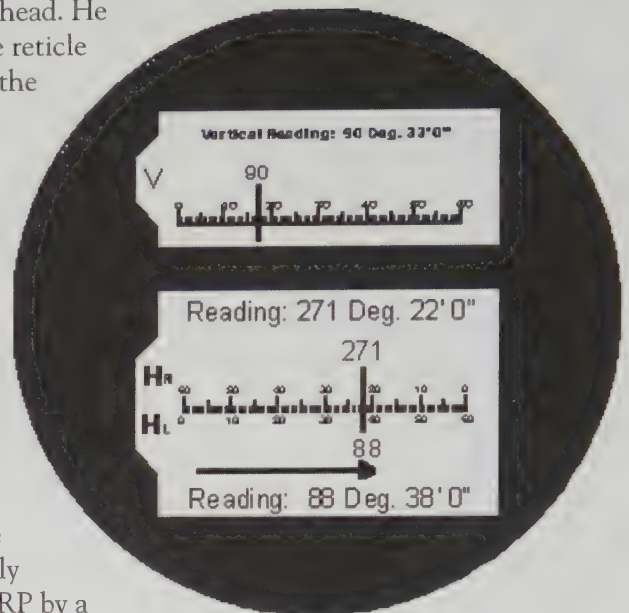
METHOD 2. Determining the range to a target using the size of the target as a representative baseline. This method takes advantage of the theodolite's resolving power. Even though you are using a smaller target (3 to 15 meters tall or wide) as compared to method 1 which uses a wide baseline of 30 meters or more.

PROCEDURE FOR METHOD 1—ANGLE B MEASUREMENT

1. The HTI team approaches the final firing point and the team leader designates the point (Point A) for the first position of the theodolite. The operator sets in the theodolite and levels the system. The optical micrometer was previously zeroed out at the ORP. You cannot zero out the vertical scale. He immediately releases the theodolite head and slews the scope to the designated target point (Angle AC). The micrometer will read 0 degrees 0 feet 0 inches. At this point, the operator can take the vertical angle reading to the target if there is any up or down angle. He writes this down in his notes. The observer will need this data for his slant angle corrections. He will attach a small fishing weight plumb under the instrument and sink a nail head in the ground.
2. The operator engages the optical micrometer and slews the head right or left until he gets a deflection of 90 degrees 0 feet 0 inches. He is now looking at Point B, and this establishes the azimuth for the baseline (Angle AB). Another operator will have measured the pre-determined baseline length. For the purposes of this example, this is 30 meters. The operator has a small fiberglass wand (tape two vertical levels to this wand to ensure it is straight up and down) in his hand that is used to mark the place where he will set a nail in the ground to designate Point B.
3. The theodolite operator will slew the head back to Point C (the target spot) and he should get a reading of 0 degrees 0 feet 0 inches on the scale. He will then slew the head again to Point B and this checks his position, his measurement, and the precision of Point B. At this point, the triangle is laid in. Points A, B and C are established with a baseline of 30 meters and a 90 degree angle at Point A to B and C.
4. The theodolite operator will lock the head of the instrument, pick up and move his instrument to Point B. The man with the wand will return to Point A and place his wand vertically on the nail at Point A. The theodolite operator will set his instrument up over the nail using the optical sight on the theodolite for plumbing the sight in. This is also done at the same time the sight is leveled. This takes a bit of practice but like surveying students can attest, with practice it can be done in less than a minute.
5. The system is leveled and plumbed directly over Point B. The operator, with the micrometer locked, slews the theodolite around until he is directly lined up with the center of the wand. Ensuring that the wand is vertical, he makes final adjustments to the location of the theodolite. At this point, the scale is at 0 degrees 0 feet 0 inches. He is pointing his sight directly at Point A.

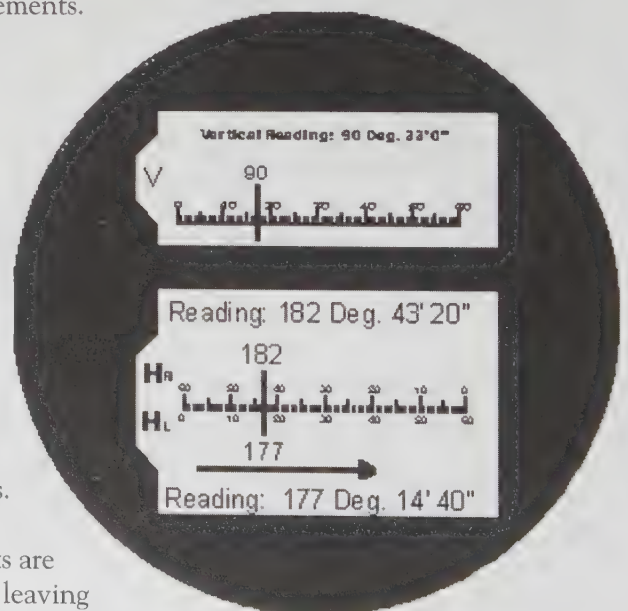


6. He engages the optical micrometer and unlocks the head. He slews the theodolite over and up or down so that the reticle is aiming directly at Point C (target). He looks into the optical micrometer and takes a reading. His direct reading is 88 degrees 38 feet 0 inches. This is written down in his notes. He will have to subtract this from 90 degrees later.
7. As a final check he will slew his theodolite back to the Point A. He should get a 0 degrees 0 feet 0 inches reading. This tells him that the original Point A is good and his taking of the reading was solid. There is another way of making your reading more precise.
8. While all of this angle measurement is going on, another member of the team is taking initial MET and ENV conditions. He takes a barometric pressure reading and air temperature reading. This is especially important when the FFP is located away from the ORP by a good distance.
9. Repeating Measurement. After the operator has slewed his sight from Point A to Point C and recorded that deflection (he converts this reading to a decimal figure using the calculator so that 88 degrees 38 feet 0 inches becomes 88.63333 degrees), he disengages his optical micrometer. This allows him to move the sight head without changing his scale reading. He slews the head back to Point A again. He re-engages the micrometer and slews his sight over to Point C. This takes another measurement that is added to the first one.

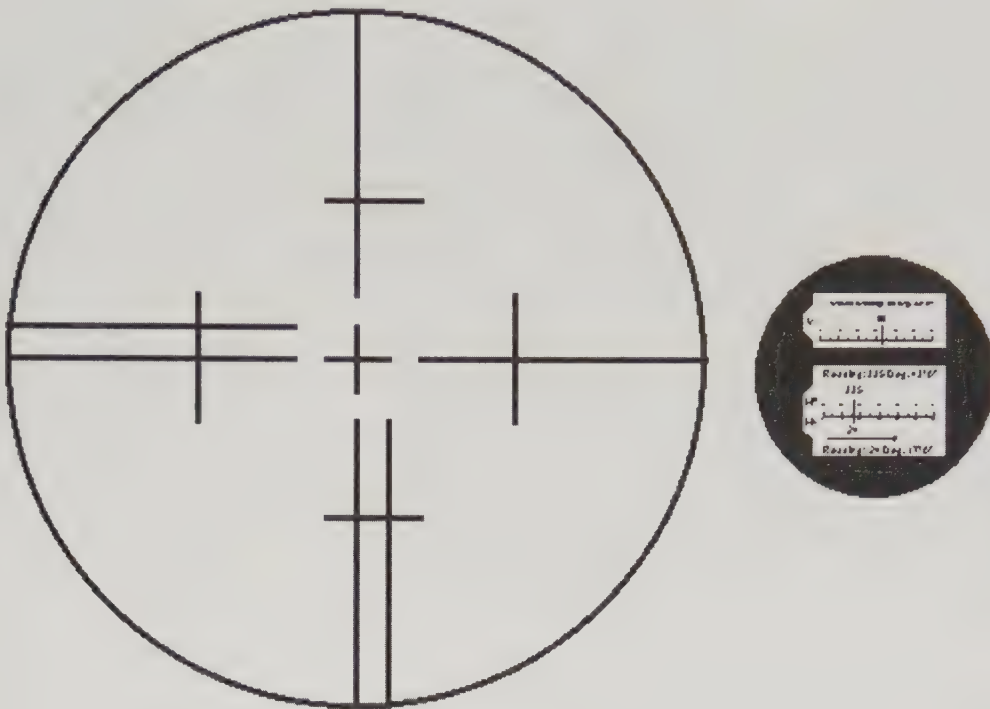


You must remember that when adding angles, they must be converted to decimal format. This is easy on a scientific calculator. This repeating measurement can be taken as many times as necessary. The acid test is the averaging. The scale in the sight should look like this now. This is on the second repeating measurement. The scale shows 177 degrees 14 feet 40 inches for two measurements.

- Your 3 readings are
 - 88 degrees 38 feet 0 inches (88.63333)
 - 88 degrees 38 feet 0 inches (88.63333)
 - 88 degrees 36 feet 0 inches (88.60000)
- Total of all readings = 265.86666 or 265 degrees 52 feet 0 inches.
- Divide the decimal figure by 3 for an Angle B average = 88.62222 or 88 degrees 37 feet 20 inches average.
- Subtract 88.62222 from 90 for the Angle C measurement = 1.37778 or 1 degree 22 feet 40 inches.



10. Once the team has determined that the measurements are true and acceptable they break down the equipment, leaving



This is the intersection through the lens of the theodolite. The optical micrometer is depicted to the right of the road main observation sight. These sights are usually in the 30X range. Because of the high quality of the lenses they make excellent spotting scopes and are quite capable of reading long-range trace. One of their shortfalls, however, is light transmission under conditions of limited visibility.

only a nail at Point A for a gun position reference. They have gathered their Angle B and Angle C measurements and have their slant angle to the target. They are now ready to begin their calculations to determine the range to the target.

PROCEDURES FOR METHOD 2 / ANGLE C MEASUREMENT

In this situation, the team is going to use the target itself as a representation of the baseline. Instead of the baseline being at the gun's position (30 meters), the size of the target (vertical or horizontal) becomes the baseline for the triangulation formula. This is the preferred method for a couple of reasons.

- Since the target is in place, you know exactly where it is positioned and won't have to make minor range adjustments. In Method 1, you may have to adjust your range based on the actual location of the target in relation to where you shot the range to (i.e. the road intersection).
- Much less chance of error when taking the angle deflections because the theodolite will remain in one place (Point A) and not have to be moved to Point B to take a deflection for Angle B.
- Less movement in the FFP area. This is a tactical problem associated with moving in your FFP enough to possibly compromise the team to security patrols that may be operating in the area. The team finishes its angle determinations and returns to the objective rally point and in the meantime an enemy patrol finds evidence of the team's activities at that FFP.
- You will get a more accurate angle to target deflection for determining the uphill or downhill slant range to target. Another critical factor when using an angular deflection method is that when you are looking

THEODOLITE CALCFORM FOR HORIZONTAL DEFLECTIONS

THEODOLITE RANGE FINDING

(Size of Target in Meters) X SIN of Angle B (Big Angle)
SIN of Angle C (Small Angle, the deflection)

ANGLE B METHOD OF HORIZONTAL ANGLE DEFLECTION

1. Locate the Theodolite at Point A on the Range triangle. This is the primary gun position.
2. Unlock the locks on the Optical Micrometer so that when you turn the turret head the scale on the micrometer will not move from "zero".
3. Fine-tune the reticle to the target to be down range point that represents Point C and lock in the optical micrometer.
4. Slew the reticle to the right or left until you get a deflection of 90 Degrees from the AC line and set a stake at Point B the desired baseline measurement away from Point A. (30 meters)
5. Slew the theodolite back to Point C and you should get a 0 reading. Recheck your angle to Point C, confirm 90 degrees. Return head to "0" reading and lock in the micrometer.
6. Move theodolite to Point B on the triangle, level and obtain Point A in the reticle. Unlock the micrometer, slew the head from Point A to Point C, and note the deflection.

ANGLE B
88 Deg. 38' 0"

7. Enter the Angle C (Step 5 above) in the calculator and convert to decimal format and press SIN.

SIN Ang. B= **.99972** 6

8. Repeating Measurements?

88.63333 Deg 88.63333 Deg 88.60000 Deg

9. Average of Repeating Measurements

88.62222 Deg 6 Angle B Average

10. - Enter "90" on the calculator

11. Hit the (-) key

SIN of Angle B Average
.99971

12. Enter the actual deflection converted to decimal format. (i.e. 88 Deg 15") to (88.25)

13. Hit the (=) key

14. This is the Angle C in decimal format.

- Hit the (SIN) key and enter in the box

SIN Ang. C= **.02404** 7

15. 8. Enter the size of the target in METERS

30 Meters 8

16. EXECUTE THE FORMULA

Data in Box 8.

Data in Box 7.

30 Meters

X

.99971

DIVIDE BY

Data in Box 6

.02404

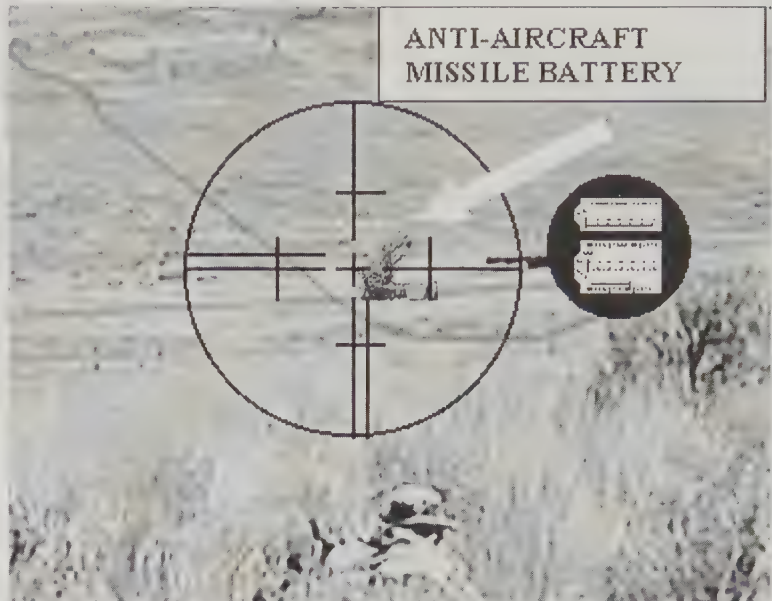
10. RANGE TO TARGET =

1247.55824 Meters

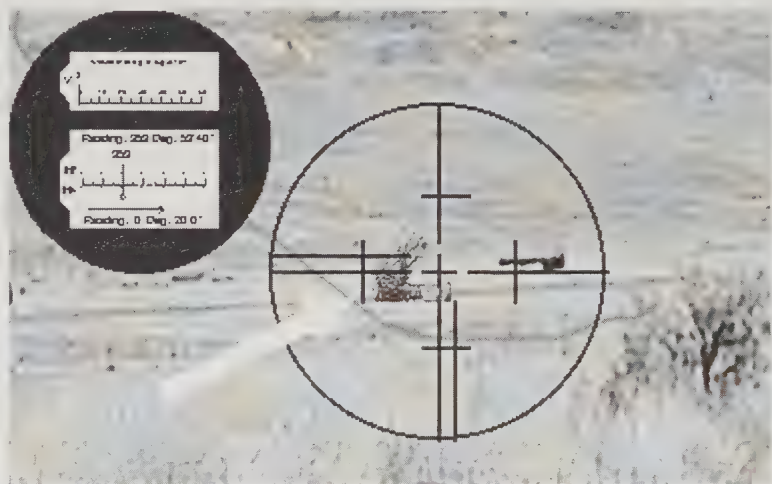
uphill or downhill at a target, that angle to the target affects the apparent height of the target. You must correct for this angle to target. More about that later.

In the picture at right, the operator is looking over his No. 1 gun. He has acquired the left side of the missile launcher and his micrometer is set at 0 degrees 0 feet 0 inches. The vertical micrometer which you cannot set to zero is showing a down angle of 8 degrees 0 feet 0 inches. Eight degrees is the angle from the gun to the target. The cosine of 8 degrees is .99027. The operator will multiply his true range in meters against this value to obtain the slant range correction. The procedures for a horizontal angle deflection are as follows:

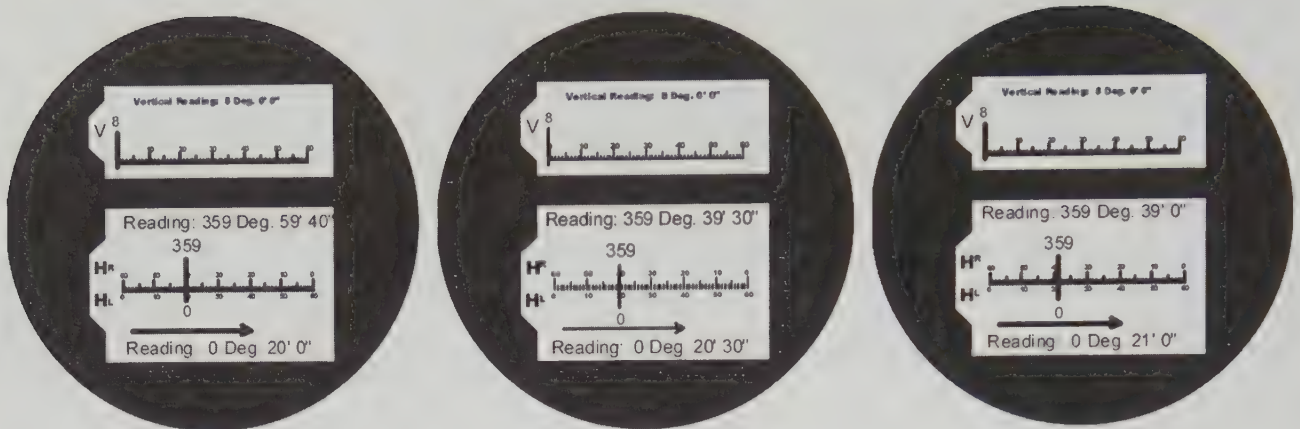
1. The team performs an area reconnaissance for the final firing position. When the FFP is located the team leader designates the position for this base gun and the theodolite is set up in this position. The instrument is leveled. For this mode, there is no need to plumb and mark the site.
2. The operator slews the theodolite head to zero the optical micrometer. He then disengages the micrometer so that he can move the head without changing the micrometer setting. The reticle is aligned with the left or right extreme measurable side of the object to be ranged. Check to ensure that the micrometer is at 0 degrees 0 feet 0 inches. The operator engages the optical micrometer and slews the theodolite head to the opposite side of the target, inducing a change in the reading on the optical micrometer. In the case here, the deflection is 0 degrees 20 feet 0 inches. The vertical deflection is 8 degrees 0 feet 0 inches.
3. At this point, the team has all the data that they need to determine the range to the target. They have the size of the target in meters, the horizontal angle deflection of that target, and the angle from gun to the target.
4. Repeating Measurement. A repeating measurement is recommended whenever the tactical conditions permit. A repeating measurement works as follows.



The operator looks over his No. 1 gun.



Anti-aircraft missile battery. Theodolite is slewed to the right side of the target for deflection.



- After the first measurement, the operator disengages the micrometer and slews the head back to the left side of the target.
- He re-engages the micrometer and dials the reticle back to the opposite side of the target for a second measurement. The 20 feet reading should continue to escalate to a 40 feet or so reading. It may vary 15 or 30 seconds. The micrometer is again disengaged and the head is panned back to the left side of the target.
- The third measurement. The operator re-engages the micrometer and for the third time, he pans the reticle across the target. This repeating measurement is much more accurate than a single reading. Do this as many times as you have time for or until you are satisfied with your measurements.
- Remember to convert your angle findings to decimal format before adding them together. You must also do this to obtain sin and cosine functions.
- Your three "Angle C" readings are:
 0 degree 20 feet 0 inches (0.33333) Range = 1,375 meters
 0 degree 20 feet 30 inches (.34167) Range = 1,342 meters
 0 degree 21 feet 0 inches (.35000) Range = 1,310 meters
- Total of all readings = 1.02500 or 1 degree 1 foot 30 inches for Angle C.
- Divide the decimal figure by 3 for an Angle C average = .34167 or 0 degrees 20 feet 30 inches average.

The Angle C method is much more desirable than Angle B method. There is much less movement around the final firing position and that means less exposure time to a potential enemy position. The team can move forward to obtain the Angle C data with the theodolite and then return to the objective rally point to calculate their data. Another team member should be taking the meteorological conditions while the range finding operations are being conducted.



With practice an operator can take an Angle C reading in about 2 or 3 minutes. The major factor is the time it takes to level the theodolite. It is critical that the theodolite be leveled before taking the measurement. This method works very well for a target that is wide. Trucks, missiles laying in the travel mode, radar vans, boats, aircraft, and railcars all work very well for determining

Angle C on the horizontal plane. We have covered the two major methods for determining Angular Deflection using a theodolite. Both of these techniques are extremely accurate, but one is much more difficult than the other method.

Determining Angle C on the vertical plane is as fast as doing the horizontal method but it requires a little more calculator use. This is because you cannot zero the vertical angle reading scale on a theodolite. It will always read something between zero and 90 degrees.

PROCEDURES FOR METHOD 2 / ANGLE C MEASUREMENT USING THE VERTICAL PLANE

Using the vertical plane (measuring the height of the target instead of the width) is in some ways desirable to the horizontal plane. Certain types of targets are much taller than they are long, especially missiles in the launch mode. Certain vans that have extendible mast antennas are much taller when that mast is extended than when it is lowered. In many cases, such as in the picture at right, you can use a full ground to top of the radar measurement because the ground line is clearly defined. This will depend on the operator's ability to see clearly defined edges.

Another factor for taking a vertical measurement is the angle of the vehicle to the theodolite position. In this photo, the vehicle is on about a 40-degree angle to the gun position. The radar is also on that 40-degree angle. In this case, although the radar is tipped back a little, you will get a more accurate angle deflection taking a vertical measurement that you will with the horizontal measurement. You also save time using the vertical measurement because you do not have to zero out the optical micrometer before taking your 1st deflection. Repeating measurements create a bit of a problem though. Here are the steps for a vertical measurement:



1. After the team leader has fixed the location for his FFP, the theodolite operator locates his theodolite over the base gun position. He levels his instrument and is ready to take the first reading. There is no need to zero the horizontal optical micrometer and you cannot lock or unlock the vertical micrometer. That reading will constantly change as long as your are moving the sight up and down. As with the horizontal method, there is no need to plumb and mark the sight other than to mark it for the base gun's position.
2. The operator places the reticle at the bottom of the target. This is the point on the target where he knows he has a solid real world measurement for height in meters and he can clearly see that point through his scope. He notes the reading for the vertical deflection. In this case, the reading is 8 degrees 15 feet 0 inches. Target height is 11 meters.
3. He will now slew the sight reticle to a point halfway up from the bottom. This is to take the slant angle setting to the target. This will also give him the angle that he needs to correct the target height's visual appearance to him based on the downhill angle to that target. The more severe this angle, the smaller the target is going to appear to him and this must be corrected for. Mid-point reading is 8 degrees 27 feet 50 inches. In this case, a 11-meter high target will appear to the eye to be 10.88 meters high for measurement. You can't tell this, but you know that target is 11 meters high. You can only slew the sight from the bottom to the top of the target based on what you can see of that target. There is no way to mentally project where the top of that target would be if the angle to the target were 0 degrees. So how do you correct for this misrepresented angle? You must take your third and final reading to correct for this optical error.

4. The sight is now elevated to the top of the target and a reading is taken. The reading is 8 degrees 40 feet 0 inches. To obtain the deflection, subtract the bottom angle reading from the top angle reading. Remember to convert your angles to decimal format to subtract.

- 8 degrees 40 feet 0 inches (8.66667 degrees) – 8 degrees 15 feet 0 inches (8.25000) = .41667 or 0 degrees 25 feet 0 inches
- Angle C (Vertical) = 0 degrees 25 feet 0 inches

5. Remember we said that because there is an 8+ degree angle to the target, that target is going to appear smaller to the operator. He can only take a reading on what he sees and cannot project where the top of the target would be on a horizontal plane (0 degree angle to target). Now is the time to correct the vertical deflection for that optical error. Here are the steps to correct the vertical deflection.

- Total height of target in degrees/minutes/seconds = 0 degrees 25 feet 0 inches
- Angle to Target = 8 degrees 27 feet 5 inches

CALCULATOR SEQUENCE

Enter > .25

Divide by

Enter > 8.275

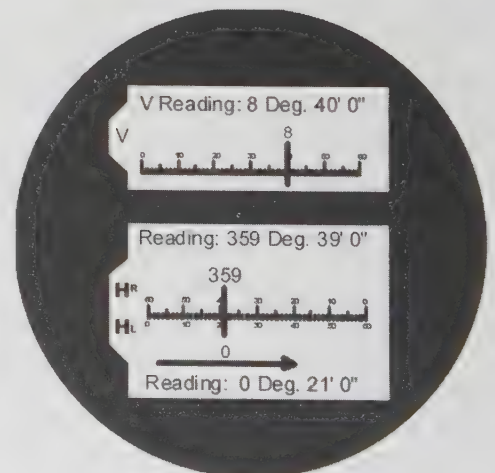
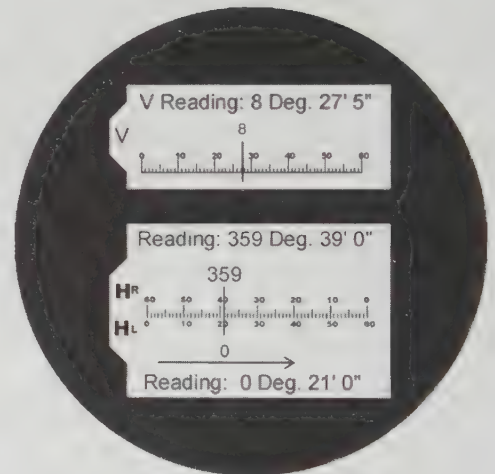
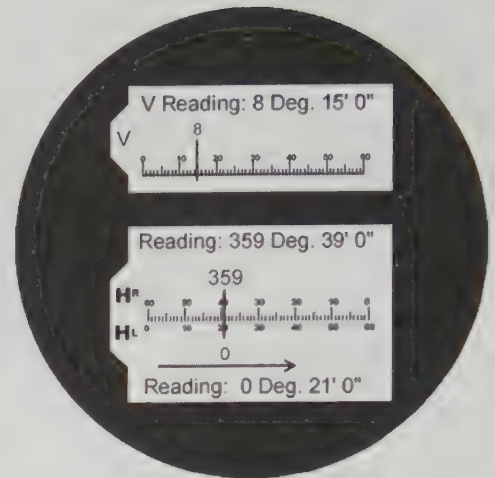
COS key

= .25263 corrected Angle C

(this is not in decimal format, but don't change it)

6. Now, how much does this minor correction affect the range to the target and the subsequent MOA elevation setting? Let's find out.

- Using an uncorrected 0 degree 25 feet 0 inches / Range = 1,513 meters / 79.75 MOA
- Using the corrected angle of 25 feet 26.3 inches / Range = 1,487 meters / 77 MOA
- A difference of 2.75 MOA at 1,500 meters = a difference in the strike of the round by 47 inches on the target. Not too bad, but can you afford it? We haven't even corrected this data for slant angle to the target and the other MET and ENV conditions. The errors add up fast.



NOTE: Whenever you are reading the angle to target and you are shooting uphill or downhill, the target is going to appear farther away from you. When you correct the deflection for this angle, your range number should be smaller. If the range number is larger, you multiplied instead of divided. Remember you still must correct the true range to target for the slant angle.

The two effects are not the same. The first, the optical error due to angle corrects the apparent size of the target for range. The second, correcting the true range for the slant angle, corrects the range for the effects of gravity.

This all sounds rather long and drawn out. The first couple of times it is. As you practice the use of the calculator and learn how to use the different memory capabilities, you will speed up.

CHAPTER SUMMARY

The shooting aspect of sniping is all about unknown distance shooting. There are a good number of target shooters out there that can put shots into the 10 and X ring all day long. That's their craft and they're the masters of it. But add the unknown distance factor to this and many of these shooters fall short. Determining the range to a target has long been one of the two major problems of military sniping. The other major problem, that being winds, affects any shooting discipline. We're all in that one together. In this chapter, you have been presented with the full spectrum of methods for determining a range to the target. Every method here is a passive method. Laser range finders are not given much credence here. When they do work, they are simple to operate, yet seem NOT to solve the problem of determining the distance to the target.



All of the methods presented—appearance of objects, mil relation, angular relation and finally

triangulation—have their place in sniping operations. Sure, mil relation can work on hard targets of large size, using the optic on the rifle. Yet, frequently the target is not where you are at the same time. This requires that you determine the range to a point on the ground. Mil relation won't work in this instance. At times, you may be able to actually measure the distance to the target using a tape measure. Targets getting this kind of attention are special indeed.



SAMPLE OF CALCFORM FOR VERTICAL ANGULAR DEFLECTION

THEODOLITE RANGE FINDING

It is important to note that when obtaining a deflection on a target that is not 90 deg. to the position of the station, there will be an error in the range. In this case "Vertical Angular Deflection" will provide the best solution.

$$\frac{(\text{Size of Target in Meters}) \times \text{SIN of Angle B (Big Angle)}}{\text{SIN of Angle C (Small Angle, the deflection)}}$$

VERTICAL ANGULAR DEFLECTION w/ Correction For Slant Angle to Target

1. The vertical scale on theodolites cannot be "zeroed".
2. Pickup the bottom of the target to be ranged and enter the reading. 8 Deg 15' 0"
3. Slew the reticle to the top of the target to be range and enter: 8 Deg 40' 0"
4. Take a mid-point reading for your slant range 8 Deg 27' 30"
5. Convert the first reading (1.) to decimal format: 8.25000
6. Convert the second reading (2.) to decimal format: 8.6667
7. Subtract smaller deflection from the larger deflection. Angle C = 0 Deg 25' 0"
Leave in decimal format and press the SIN key. Enter here. SIN Ang C = .00727
- CONTINUE WITH STEP 8 IF THERE IS SLANT ANGLE INVOLVED IN ANGLE C**
8. Correct Angle C for Slant Angle Optical Error.
 - Enter > Angle C Reading =
 - Divide by
 - Enter > Angle to Target in decimal Degrees.
 - COS key
 - = Corrected Angle C Reading.42397 Deg.
Corr SIN Angle C = .00740
9. - Enter "90" on the calculator
 - Hit the (-) key
 - Enter the actual corrected Angle C deflection in decimal format. (i.e. .10' 22") to (.17278)
 - Hit the (=) key
 - This is the Angle B in decimal format. Convert to DMS.
 - -Hit the (SIN) key and enter in the boxSIN Ang. B = .99997

10. Enter the size of the target in METERS

11 METERS

11. EXECUTE THE FORMULA

Data in Box 8.

Data in Box 7.

11 Meters

X

.99993

DIVIDE BY

Data in Box 6

.00740

11. RANGE TO TARGET =

1487 Meters

There are a couple of other methods that are addressed in Chapter 11, "Target Analysis." As with Chapter 2, constant practice with the scientific calculator and your special instruments are a key to success. Allowing yourself to get rusty using these advanced techniques only ensures misses on first or second shots at these extreme ranges. On one hand that may be not too bad, on the other, well you know the rest. In sniper matches that I have attended, the biggest factor that separates the wheat from the chaff on field shoots is determining the range to the target. However, there are tricks. For these, refer to Chapter 9.

1. Extract from *Naval Gunnery Text, 1917, General and Approximate Deductions*, Page 59.
2. From TC 31-20-4, *Special Operations Sniper Training and Employment*, Oct. 1996, P. 3-41.



Training the Hard-Target Interdiction Operator

When the first proposal was written in 1989 for a Hard-Target Interdiction (HTI) program—the Special Operations Target Interdiction Course (SOTIC) at Fort Bragg—there was a lot of discussion about how an individual should be prepared to be a HTI operator. The initial draft was much more narrowly focused than what the program evolved into (although it still doesn't officially exist). It was written that there would be four-man teams. That evolved into training elements that were indigenous to whatever special operations element were using the program (i.e. a Ranger Squad, a Special Forces A-Team, or a SEAL Squad). It is still recommended that whatever the operational element, four men remain the operational minimum for this type of mission.

There are three reasons for this minimum size specification. They applied in the original document in 1989 (see Appendix D), and they still apply:

1. Extra equipment would have to be carried by the element. Part of this is due to the sheer size and weight of the equipment used in this mission profile. Fifty-caliber rifles weigh between 25 and 40 pounds each. Four rounds of ammunition weigh in at 1 pound. Specialized range-finding equipment and radio equipment still has to be used.
2. An increased level of flexibility is available. Some of the targets may provide the opportunity for more than one heavy weapons system to be employed. For example, shutting down an enemy airfield could be accomplished by employing two HTI teams. Each team could carry two or three weapons to be fired side by side. The fourth man will be the observer for the three shooters.
3. Security is always an important aspect. Indeed it is the highest principle. The nature of HTI operations dictates deep penetration missions. Extra people are extra security. You may only employ one heavy rifle. You would have one observer, leaving two men for security and “ammo bearers.”

In Chapter 1 it was mentioned that the first HTI course consisted of 16 personnel, 13 of whom were previously trained Level I SOTIC graduates. The remaining three were a little different. There was one Air

Force weatherman and two U.S. Army Explosive Ordnance Disposal (EOD) personnel. I won't get into the reasons for having three non-SOTIC personnel in the course; let's just say it was professional courtesy at the time. So here we were with 10 SOTIC Level I graduates, three SOTIC Level II graduates and three non-sniper qualified individuals. These shooters were integrated into 4-man teams. One team was made up entirely of personnel from the 2nd Ranger Battalion of which one was non-qualified as a sniper and three were trained as snipers at Fort Benning, GA.

At this point, I should explain what makes a Level I and a Level II shooter. This designation exists only within Army Special Operations. The Army Special Operations command recognizes only two schools of enough quality to produce a Level I shooter. These are the SOTIC at Fort Bragg, NC, and the Marine Corps Scout Sniper Instructor Course at Quantico, VA. The five Special Forces Groups that are operational also will run sniper training programs. These vary in length from 2 to 6 weeks, and sometimes more. These courses are run by snipers who have been to the Level I course at Fort Bragg. They are allowed to designate personnel that they have trained as Level II snipers. Level II snipers can only train overseas non-U.S. personnel. There was a time that SOTIC snipers had to certify annually with their assigned SWS. This has come and gone with little emphasis received by the chain of command. Any sniper out there knows what a nightmare dealing with the command for training opportunities can be. It's no better in Special Forces, and to be honest, it is probably worse. This was the team breakdown. It's important to be familiar with this breakdown as it sets up the results of who did well and who didn't do so well and their previous training and qualifications.

- Team 1: 4 U.S. Rangers, 3 Level II and one non-qualified.
- Team 2: 4 U.S. Army Special Forces, all Level I qualified.
- Team 3: 2 U.S. Army Special Forces Level II, one EOD, one USAF weatherman.
- Team 4: 3 U.S. Army Special Forces (one Level I, one Level II and one non-qualified), one EOD man.

Sniper weapons systems were a bit mixed up also. All .50-caliber rifles used were Barrett Light .50s. Most of these weapons came from the Joint Operational Stocks at Lexington, KY. These rifles came with Swarovski 10X scopes with the "Christmas Tree" reticle pattern that we're not much a fan of. The Rangers brought 2 guns with 10X Leupold & Stevens M1A Ultra (Mark IV, M-1) scopes, and EOD brought two guns with 16X Leupold & Stevens M1A Ultra scopes on them. All of the guns with Swarovski scopes on them were switched over to 10X Leupold & Stevens M1A scopes. The SOTIC detachment at 1st SFGA wasn't fond of the Swarovski scope with that reticle pattern in it. That system doesn't lend itself to precise corrections for MET and ENV conditions and a good way to index elevation settings.

Training a shooter or any other operator to handle



Barrett rifle with L&S M1A Ultra 16X scope. One-degree angle base.



Barrett rifle with Swarovski 10X scope with the "Christmas Tree" reticle pattern. One-degree base.

heavy-class sniper rifles and the mission of HTI is a little more involved than training field snipers. A field sniper or a sniper going through the SOTIC course goes through a pretty standard training regimen that usually consists of the following:

- Technical training on the systems to be used, including the rifle, optics, backup sights and maintenance of the systems. (M-24, M-40 etc.)
- Basic and advanced rifle marksmanship training.
- Camouflage and concealment.
- Sniper marksmanship.
- National Match Course 3 position training (SOTIC only).
- Field skills.
- Very limited training on ENV and MET effects.
- Very limited mission planning skills and the use of intelligence assets.
- Limited exposure to NVD shooting skills and zero procedures.
- Possibly 1 field training exercise (FTX or STX).

Hard-Target Interdiction operators' training skills are considerably different, much more complex and intense. We determined through some careful analysis that a heavy-class rifle shooter need not be trained as a sniper beforehand because the marksmanship skills are not necessarily the same as with smaller guns. Experienced rifle coaches out there will wince at this. Our experience has shown that a person trained as a Level I shooter, or a master class high power shooter did absolutely no better with a heavy class gun than did a previously untrained shooter. In a couple of cases, very highly capable shooters (Master Class) could not make the heavy class guns work. Of additional interest is their unwillingness to acknowledge their inability to make them work and blamed the problems on the guns and ammunition. The purpose of this chapter isn't to explain why it isn't the same, but how an HTI operator has been trained and the lessons learned along the way. By the way, these methods work the same for civilian match and fun shooters to make their systems more fun to shoot. As was stated before, the training profile is a little different for the HTI operator. It looks something like this:

- Introduction to Hard-Target Interdiction weapons and special equipment.
- Theodolite range-finding and advanced range-finding procedures.
- The use of scientific calculators.
- Introduction to exterior ballistics and the use of the .50-caliber data tables.
- Classroom training drills using methods taught in correcting for MET and ENV conditions. (20-30 hours of intensive number crunching).
- The use of MET intelligence.
- Mechanics of shooting large bore, muzzle brake rifles (heavy-class guns).
- Daylight and night zero procedures.
- 500, 1,000, and 1,500 meter known distance grouping (day and night).
- Integration of multiple shooters under one observer.
- Integration of multiple HTI teams under a master observer/director.
- Live fire extreme angle shooting methods.
- Live fire application of fire methods.
- Target analysis
- Mission planning
- Multiple full profile dry and live fire missions.
- Use of suppressed weapons systems.

The above just scrapes the surface of material that is covered in HTI training. These classes are not just one-hour lecture classes. They are all reinforced with hands-on, live fire procedures.

As is implied by the title of this chapter, we are going to discuss training the HTI operator. There is a parallel between conventional sniping and the HTI sniper profile. No matter the number of personnel that are in the element, you have only two sniper-specific specialties to be worried about. These are shooters (the guy that is actually behind the rifle and pulls the trigger) and observers. A trademark of SOTIC has always been that the most important person in a sniper team as well as the most experienced is the observer. This individual is also commonly referred to as a “spotter.” This is not very



accurate as the observer does much more than spotting targets. His name might well be the “director.”

The sniper or shooter has only a couple of tasks, none of which are particularly difficult. He identifies the target that the observer gives him, he puts the sight settings for elevation and windage that the observer calculates and gives him based on range, MET and ENV conditions. He then pulls the trigger, reloads and awaits his next command. Did you see anywhere in the above text where the sniper directs any action? No. That's because the trigger puller is essentially the executor of the observer's will. The observer detects and indexes targets, determines the range, corrects for MET and ENV conditions, gives wind calls and makes additional corrections as necessary. Given the above information, which job do you think is the more difficult?

We used to constantly stay on the shooters to do exactly as the observer told them. This is especially true in training. If the shooter second guesses the observer's calls or his data and shoots his own findings, the observer will never know if his was correct. More importantly in the event of a miss, he will be correcting off of his own data and won't realize that the shooter didn't shoot his data; he second guessed and shot his own. That never works. The observer determines target speed, and gives the lead, integrated with any winds that may be present. The shooter leads or trails the target as directed and pulls the trigger. Pulling the trigger isn't that difficult. In the HTI environment, the observer is the master of all. His word is final and must be followed instantly and with precision.

The focus of this chapter is on the marksmanship skills of the individual shooter. This is followed up with the necessary training to integrate that shooter under an observer and commands used to control that shooter. The integration of two or more shooters under the control of an observer is next. It is quite difficult to get three shooters to shoot the same data on their guns. One observer giving data and corrections to two or more shooters is tough and demanding work and requires total concentration of the shooter. We are also going to talk about observer-specific training. Much focus in a sniper school is on the training of a sniper and the observer gets training residually as a result. Since the observer has so many difficult and timely decisions to make as an HTI operator, special training is recognized and required.

The discussion from this point forward will focus on the following categories of training:

1. Marksmanship training procedures for the individual shooter (STR).
2. Special training skills for the observer (OBS).
3. Integration of the observer and the shooter. This will include means of communication between the OBS and the STR. The special shooter and observer dialogue is covered here.

MARKSMANSHIP TRAINING PRINCIPLES FOR THE INDIVIDUAL SHOOTER

While much of the training between light-, medium-, and heavy-class is comparable, there are some subtle differences. A .308 or light-class shooter may shoot up to 120+ rounds per day. This is especially true when training in the three positions used in National Match competition. At SOTIC in a Level I or II course, almost half of our ammunition was used teaching people how to shoot. Medium-class guns such as the .300 Winchester Magnum, or .338 Lapua Magnum are too punishing and the round count drops to about 60 rounds due to the recoil of these powerful weapons. Training of the individual shooter in the heavy class requires a careful approach. Fifty-round days are considered heavy.

The Human Engineering laboratory has placed a 50-round-per-day limit on shooting these weapons. The noise and intense overpressure causes damage. Instructors that are around the guns and in their baffles can

easily become ill from the overpressure of shot after shot. There is no getting used to it. In 1993, my sniper partner and I were both ill a day after a shoot where the unit's officers were introduced to .50-caliber sniper rifles. We were around the guns all day long without a break. The next day we were both sick from the blast overpressure. The shooter and observer are in the best position. That is right behind the gun. An instructor who is constantly kneeling down to talk with the shooter or observer is placing himself in the "baffle zone" and is getting hit with some pretty strong hits of overpressure as a result. An instructor has to be intensely aware of where he is when he is on the range. This is a major safety issue.



Hard-Target Interdiction teams executing crew drill procedures.

There are several subjects that the individual shooter should have received instruction in before firing live rounds for marksmanship training. These are classes that teach the basic mission profile, the equipment, weapons and special materials needed for this mission type.

- Equipment Used in HTI Missions.
- Introduction to the HTI Training Profile.
- Sight Adjustment and Zero of the Heavy Rifle
- Weapons Care and Maintenance

The above material is presented in book format with this incremental learning process in mind. For military instructors, Appendix B has a detailed program of instruction and a suggested training schedule. With these basic classes a shooter is ready to begin the training necessary to proceed to live-fire range work. We will assume from this point forward that the operator to be trained is fully familiar with the weapon, optics (day and night) and their manipulation, and any special equipment to be used except range-finding equipment. The operator is also familiar with the maintenance procedures and takedown procedures for his rifle.

One of the early problems that we found was that not just any fully trained sniper could effectively and accurately fire a heavy-class sniper rifle. Of course, the first assumption was bad ammunition or that the guns wouldn't shoot. Well, the ammunition problem was definitely part of it. But to assume that the world's finest gunsmiths (Gale McMillan, Earl Reddick, etc.) couldn't build accurate rifles was folly. These guys knew that military ammunition was substandard so they went out and got or made some very fine ammunition to test their rifles with. That makes good sense. So here we have this problem: Why could these guns shoot with good ammunition at the builder's range but not on a military range? We had to discover the answer to this question. In Chapter 4 there is some discussion as to why this is a problem. It deals with the human factors about intimidation and fear of the big gun (admitted or perceived). There is a mechanical reason that makes shooting these big guns a little more difficult. This is the presence of a muzzle brake on the guns.

Highly Efficient Muzzle Brakes

If you ask any shooter what the job of a muzzle brake is, he will respond correctly that it reduces the felt recoil on the shooter's shoulder. When asked how this is accomplished, he responds "the gasses pass through the muzzle brake behind the bullet and pulls the rifle off the shoulder." This is partially accurate. You will find comments almost exactly like these written in articles in periodicals. I submit that there is another force involved in shooting rifles with efficient muzzle brakes.

In a Navy test conducted on the Barrett Light .50 rifle, they stated that the muzzle brake reduced the recoil by 72 percent. For the brake to be that efficient, some braking action must take place before the bullet leaves the bore of the gun.

Inside of the barrel of the rifle, with a bullet in the chamber, there is approximately 16.0 cubic inches of air in front of the bullet. Before the rifle is fired, this column of air is not moving.

At the instant the rifle is fired and the bullet begins traveling down the bore of the rifle, this column of air is forced out of the barrel at 2,910 fps (M-8 API). This column of air will enter the muzzle brake. The air will go through the brake, as do the gasses behind the bullet. It will not be as efficient as the hot gasses because the bullet does not seal off the front of the brake, forcing the hot gasses through the baffles of the brake.

Although the air column is not as efficient as the hot gasses in reducing the recoil, it still does happen. The reducing action is done by "pulling" the rifle off the shoulder of the shooter. The column of cold air does the same thing, although to a lesser degree. When this happens, the rifle will greatly enhance any muscling action of the gun that is being input by the shooter.

With the above information in mind it is easier to realize why certain shooters cannot make the big-bore, muzzle-brake guns shoot accurately. Trained snipers support the toe of their gun with their non-shooting hand. Some schools advocated putting a sand sock or something similar under the toe of the gun. I advocated the use of the non-firing hand for the field sniper. This allows the sniper to move the gun quicker from target to target. Also when indexing a holdoff for winds or on a moving target, the hand makes a smoother movement than does a bag. The bag may snag or suddenly drop when the contents shift. But "bag" shooting did have a bright spot.

When training snipers how to engage moving targets using the ambush technique, a bag stabilizes the gun for a better shot product. Ambushing is a method where the sniper aims his rifle at a predetermined spot in front of a moving target. The target moves toward the center of the reticle and meets with the indicated lead on the reticle (1.5 mil for example). When the target meets with the lead, the sniper fires the rifle. It is a trained reflex. When the reticle meets the desired point on the target, the trigger finger moves and the rifle fires. Because of the gun's low recoil (light guns) it was easy to control the rifle. Light-class guns do not have muzzle brakes, nor do most medium-class guns. Called "free gunning," supporting the toe of the gun with the non-firing hand is an excellent technique. However, with large-bore, muzzle-brake guns where there is a high volume of air in the barrel this doesn't necessarily work.

FUNDAMENTALS OF THE SHOOTING POSITION

Shooters who were trained at SOTIC, 1st SFGA were trained NOT to input any shooter control into the rifle. They sandbag the front and the rear of the rifle. The swiveling bipod system as found on the Barrett leads to major problems in weapon stability. The shooters do not place their non-shooting hand under the toe of the stock to support it. They are taught to merely place their shoulder against the recoil pad of the stock, lightly. They must concentrate on squeezing the trigger without disturbing the lay of the gun. This is no different than firing any other weapon. Once the rifle is fired they must let the rifle move and settle without influencing it in any way. Once students master this technique, they show an incredible ability to use the rifle accurately.

Some shooters can pick it up very easily. Some shooters can never get it, and then there are the naturals that can do it without any special instruction. Two shooters at SOTIC, 1st SFGA recently placed 7 shots on a head and chest sized steel target without a miss at 1,535 meters. They calculated all the conditions and determined the range with a theodolite.

Training the HTI operator for this fundamental position behind the gun is the beginning of the instructional process. Behind the rifle the shooter must lay directly in line with the bore. A line is drawn down the bore of the rifle into the shoulder and through the right (or left for left handed shooters) buttocks and eventually through the calf of that same leg. This sets up the body to accept the recoil and energy straight through the body. This ensures that the rifle will (or should) recoil straight back. The muzzle should jump straight up and down. The more the body is off to one side or the other, the more the rifle will be pulled off the gun/target line in the opposite direction of the lay of the body. I will try to put into words the process that happens when a shooter fires a heavy-class rifle incorrectly.

1. The sniper takes the rifle up in the standard position using his non-firing hand to support the toe of the rifle. The rifle weighs 35 pounds and is difficult to control because of the weight and balance of the gun.
2. The sniper has his body slightly to the left of a good line from the bore through the shoulder and down the leg and calf.
3. As the sniper picks up his target in the scope, the scope is about 4 feet to the left of the target. He compensates for this by pulling the gun to the right to compensate for the reticle position on the target. At this point, he has a misalignment of his body and he is muscling the gun onto the target.
4. The sniper pulls the trigger on the rifle, the striker impacts the primer, and the bullet starts accelerating down the barrel. The cold air in front of the bullet is being compressed in the barrel by a rapidly



Tail of gun is supported by a bag, not a human. The front of the gun is dug down to get the gun low to the ground.

- accelerating bullet.
5. The "cold air piston" in front of the bullet clears the crown of the barrel and enters the muzzle brake of the gun and instantly begins to expand because of the expansion chambers in the muzzle brake.
6. A percentage of this cold air piston is pushed out of the bore of the brake. Another percentage of this cold air piston is rammed into the baffles of the muzzle brake. At this point the muzzle brake is beginning to do its job, yet the bullet is inside the bore.
7. The muzzle brake goes into effect by pulling the rifle away from the

shooter because of the arrowhead shape of the brake. The shock to the shooter from the blast causes a momentary relaxation of the muscles, particularly the ones controlling the position of the gun. When this happens the gun begins to sway back toward the point where “natural point of aim” would occur. This would be back to the left.

8. At about this point, the bullet reaches the crown of the barrel. The gun is now to the left of the original point of aim because of the action of the muzzle brake and the shooter muscling the gun. The bullet travels toward the target and impacts to the left of the point of aim.
9. At this point the sniper probably dials in a correction because he thinks the wind was wrong or some other data needed correcting. After indexing this correction, he again picks up the rifle and muscles it into position and the same thing happens.

The error in the above process is continuous and grows exponentially. Snipers from the 2nd Ranger Battalion told me that the command was going to ship their Barrett rifles back until the newly trained snipers showed chain of command that the guns could be made to work. The Ranger Battalion’s operational ammunition is Mark 211, Mod-0 and M-8 API in addition to Ball and Tracer shots.

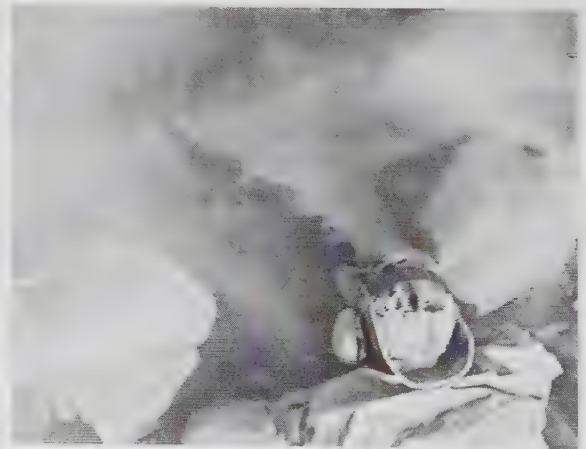
The final part of the position and shooting process that the individual operator must understand is overcoming the urge to “get the gun back on target.” SOTIC—and any other school for that matter—teaches a sniper to get his rifle reloaded and back on the target as fast as possible. This is good sense. Many police sniper scenarios go bad because a follow-up shot wasn’t ready. Sacramento sound familiar? HTI operators must be trained to let the gun settle down after the shot goes off. Again, because of the action of the muzzle brake, a shooter mustn’t get back on the gun too quickly because of disturbing the dynamic action of the shot going off, muzzle brake action (cold and hot gasses) and the recoiling of the rifle.

In the picture below, the shooter is completely relaxed among all that blast and debris. All things being perfect, the shooter will look through his scope after shooting and see that the scope is looking at the sky. This is because the gun will settle down on the tail after the shot goes off. This is the desired sight picture after the shot goes off.

So let’s summarize where we are at this point. We have discussed:

- The differences in training between field snipers and Hard-Target Interdiction operators (shooter related).
- The value of the observer to the shooter.
- Some factors that affect the shooter when shooting heavy-class rifles.
- The basic classroom requirements before pulling the trigger for the first time.
- Effects of highly efficient muzzle brakes.
- The requirement to isolate the gun from the shooter (bags front and rear).
- Fundamentals of the shooting position, from bagging the gun to follow-through after the shot.

The basic position behind the rifle is easily taught in the classroom using videotape of previously trained shooters. Explain the effects that are listed above. Then get the shooters down on the ground behind their rifles in a dry fire environment. This is a fast and simple process to be followed up by range work. Typically, a sniper course enters the live fire process by initially zeroing the rifles and then doing grouping exercises. At SOTIC and SOTIC courses run by the



Learning to live with the blast and dust.

individual SF groups, the zero process was followed up with National Match Position Shooting for 4-6 days depending on the unit. The same is true for a Hard-Target course. The zero process is done for initialize the scope, rifle, and data tables to the shooter so that the grouping process may begin. However, before we get into the grouping drills and exercises, you should understand something about the zero process. As explained in Chapter 6, you will take the shooter through the technical zero process as explained for the type of optical system that you are using. You will fill out the zero cards with the data that is specified.

What isn't mentioned in that chapter is that a zero changes with the shooter's skills and experience. At SOTIC, USAJFKSWCS, my sniper partner and I were discussing why groups seemed to shift with all the shooters at different times in a course. After the guns are initially zeroed with the Palma iron sights and then with the Leupold & Stevens M3A scopes, the National Match training began. This involved standing off-hand shooting at 200 yards, sitting rapid fire at 200 yards, prone rapid fire at 300 yards, and prone slow fire at 600 yards. If time allowed the shooters were exposed to iron sight shooting at 1,000 yards using the 1,000 yard competition bull's-eye target.



The next phase of the course was grouping drills at medium and long range with the optical sights. We noticed that some shooters had a difference in the points of impact from when they zeroed their optical sights at the beginning of the course. By the time they shot through their optics for the first time, they had shot over 600 rounds with iron sights. At that time, we didn't pay much attention to it. We just had the shooters re-slip their BDC and windage rings to zero conditions. Over a short period of time, we noticed a pattern of changes in the zero shifts. They occurred at the following points in the training:

- After National Match iron sight shooting and during the grouping drills with optical sights.
- Instantly upon beginning snap engagements. Head shots at 200, 300, and 400 yards. Three-second exposures at all ranges. These are 1st SFGA standards and not the same as SOTIC at USAJFKSWCS. This zero shift occurred in about 7 or 10 shooters.
- Engaging moving targets. Some shooters could not account for misses that they had during moving targets. Good wind calls combined with the correct leads were not hitting targets. We had the shooter engage head shots at a stationary target. There was a zero shift in a number of shooters, but not for everyone. At that point, we had the shooter again re-slip the BDC and windage knobs of the scope.
- During field shooting exercises. A smaller number of shooters had zero changes during field shoot exercises.

There are two conclusions that can be drawn from this.

1. The shooters' systems are actually encountering zero shifts. We discounted this because of how it was happening to shooters at the same point in the course. The instructors also checked the guns for mechanical problems. This was rarely the case.
2. The biggest number of shooters with zero shifts occurred at the major shifts in training in the course. For example, from iron sights to optical sight long range grouping. Then a fewer number at snaps and a fewer number at movers. Therefore the more experienced shooters became with their systems, the fewer the number of zero shifts.

With the possibility of a zero change, or more accurately, with the inevitability of a zero change, especially

in heavy-class rifles, we are ready to proceed with the different range scenarios to train HTI operators. As with most instructional methods, an incremental approach starting with the basics and working through the advanced procedures is used to train HTI operators. Now that the shooter has zeroed his rifle and we understand some of the problems the trainer will encounter with that zero, we are ready to proceed with the initial grouping exercises used to get the shooter familiar with the system, the ammunition, and its capabilities. This concept is based on 4-man elements, however, it is often tailored by the SOF element using the technique. Whatever the size unit involved, there is always a shooter and an observer.

KNOWN DISTANCE SHOOT #1 – 600 METERS: SINGLE SHOOTER WITH OBSERVER

The focus of this exercise is to get the individual shooter used to his rifle and to maximize its capabilities. It is recommended that the shooters use a single type of ammunition. If possible this should be their combat load. This is not always possible. Many units have Mark 211, Mod-0 on their war pallets, but are saddled with M-8 or even worse, M-33 Ball, for training. Not all Ball ammunition is bad—it depends on the lot number. Shooters with bolt-action guns, whether they're single-shot guns or magazine repeaters, should shoot single shots, individually loaded. This optimizes the precision of each and every shot. An observer must be behind every shooter. Because of the muzzle brake design of these guns, the observer should be behind and above the shooter much as a competition coach would be. If this doesn't sound tactical, know that being beside the shooter will not be successful anyway. You must be in the narrow cone behind the shooter that is between the vents of the muzzle brake.

Referencing Chapter 6

During this range exercise the shooters will not be concerned with the elevation and windage corrections needed for MET and ENV conditions. At 600 meters these effects do not really mean too much. The only effect that does matter is the temperature of the ammunition. The rifles all have SAC zeroes on them. If the ammo is 100 degrees outside, the shooters will have to compensate by dropping their elevation settings by 2 MOA. Winds definitely will have an effect at this range. Previously trained snipers will be tempted to call wind data based on their experience with 7.62mm rifles and some will make wind calls based on this. This habit must be broken and the observers must determine the wind value in miles per hour instead of MOA or mil holdoffs. Part of the reason for this is the different wind deflections for the different types of ammunition.

Referencing Chapter 4

An instructor must be aware of the things that are mentioned here regarding the human factors. In every circumstance that I instructed shooters with .50-caliber rifles, I noticed a trend when shooting groups. The guys start out kind of rough, and after a couple of groups, they go sour behind the gun. The groups open up. I started enforcing the guys getting off of the gun after 3-4 groups. The pace at which they shoot must be carefully monitored. The faster they shoot, the worse they will shoot, especially when first starting out. During the first grouping session, I recommend that shooters take a rollover break after 2X 5 round groups. This only needs to be a couple of minutes. If anything it ensures that the shooters don't allow their position to break down to where their groups are affected. Enforced breaks ensure that positions stay refined. Allow the shooter to fire 6 each 5-round groups. Roll the shooter and observer over (if you're not familiar with the term rollover, it means have them switch places) every 10 rounds fired, or after 2 groups. The observer and the instructors should not allow the rate of fire to go faster than 1 round every minute or two. Instructors ensure that the observer follows protocol and passes data the same way every time. There is a good point for this procedure as the payoff shows up when an observer is controlling three guns.

This is a good point to start talking about the observer's job. He must determine many things as

mentioned before. During a known distance shoot, the dialogue is much shorter but should still follow strict procedures. The observer passes bits of data to the shooter that the shooter uses to index a target, set an elevation and windage setting, execute a final wind holdoff and shoot the rifle. This “dialogue” gets more complex as the range scenarios become more advanced. There are more control procedures as you add guns to the team. As we progress through the training scenarios, we will outline the changes in the observer’s data. The shooter also has a degree of responsibility in this. Every piece of information that the observer passes requires a response from the shooter so that the observer knows he is getting the point across. The observer’s information for a known distance shoot contains the following data:

1. Target Identification and Location
2. Elevation Setting
3. Windage Setting
4. Observer’s desired hold on the target. Explanation: While the observer may give the shooter a windage setting this does not mean that the shooter will engage the center of the target. This is true for both human and materiel targets.

The dialogue is a technical pass of information from the observer to the shooter(s) and it contains the above information (for the purposes of known distance, single gun shoots). It sounds something like this:

The observer needs to ensure that the shooter is doing a couple of things while all of this is going on. He looks downrange at the target, yes, but he should keep an eye on the shooter also. Instead of staring downrange at the target looking for the trace of the bullet on every shot, he should look at the shooter while he is shooting a group. The spotters on the target will tell the observer where the group formed. The observer should do a quick mental checklist while a group is being shot:

1. Is the shooter’s position sound and comfortable? Can he reach everything that he will need to shoot without breaking away from the gun to do it? Nothing is more annoying than for a shooter to break away in the middle of a group to grab something or set something up that should have been done already.

OBSERVER’S COMMAND

“TARGET” “BULLSEYE TARGET POINT 16”

“ELEVATION” “INDEX 17.50 MINUTES”

“WINDAGE” “INDEX 3 MINUTES LEFT”

After a “READY” from the shooter, the observer gives the shooter a “HOLD” CENTER!!! Command.

SHOOTER RESPONSE

“IDENTIFIED” Shooter crosshair on Tgt

“INDEX” “17 MINUTES ELEVATION”

“INDEX” “3 MINUTES LEFT” follow by “READY” after windage is set and shooter is on gun and on target.

After the observer calls “HOLD CENTER”, the shooter has about 2 seconds to get the shot off.

2. Is the gun neutrally bagged under the toe of the gun, and is the position sturdy and durable? I have seen shooters stuff their hand under the toe of the gun, even with a sandbag there. They did this because after the first or second shot in a group, the bag sagged and instead of resetting it, they “boffed” it by going to their hand and muscling the gun. The results on the target were instant and obvious.
3. After giving the elevation and windage setting, observe the shooter and ensure that he is setting this number correctly. This isn’t second-guessing him, it’s preventing a silly mistake in training and preventing disaster in a real operation.

4. When the shooter says "READY," is he really ready? Is the gun again ready to shoot? On semi-automatic rifles, the observer watches to ensure that a round went into the chamber, if this is possible. Sometimes there are too many things going on to do this. On a training range though, back up the shooter. If the observer is not sure if the shooter is on target, he ensures that all is correct by saying: "SHOOTER, IDENTIFY TARGET." The shooter repeats not what the observer said, but what the shooter has as a target. He should reply, "TARGET, BULL'S-EYE TARGET 16."
5. During and after the shot goes off, the observer watches the shooter to judge his actions during and after the shot. Does the shooter jerk the trigger? Is there evidence of muscling the gun (white tips on fingers, twitching muscles, strained facial muscles, etc.)? Did the shooter follow through the after-shot action OK? Did he try to get up on target too fast, or did he flinch after the bang of the gun?



This shooter is in mid-recoil. You can actually see the climbing angle of the rifle. Notice that while the shooter's eyes are closed he is not flinching. There is no facial muscle strain. This shooter looks very relaxed on the gun.

The final point to be made during this first range scenario deals with the shooter's manipulation of the sight system on the rifle. Note that in the photos in this chapter, most of the scopes are Leupold & Stevens Mark IV, M-1 of 16X or 10X. Any scope that uses 1/4 or other MOA value increments on its scope can be difficult for the operator to get used to. When quickly indexing range changes or elevation adjustments, it gets easy to "get lost" on that knob. On a Leupold & Stevens Mark IV sight, each revolution equals 15 MOA (refer to Chapter 5).

With this in mind, it is recommended that the shooter practice his indexing procedures each and every time that the observer indexes the shooter to a target. We made it standard procedure for the shooters to return their elevation knobs to dead zero when they were away from the gun. For example, at 600 meters, the elevation setting is 17.50 MOA when using Mark 211, Mod-0 ammunition. After the shooter is finished shooting his string of shots, he goes back down to 0. Here is a list of events after which the shooter should zero and re-index his elevation and windage settings to practice sight manipulation. It should be enforced by the observer:

1. Whenever the rifle is put into its case or is walked away from on the range.
2. On the range the shooter indexes elevation and windage settings given him by the observer. While shooting X5-round groups, leave the elevation settings alone. After completion of a X5-round group, re-index to zero.
3. Whenever the shooter and observer are rolling over and exchanging the positions, index the sights to zero.
4. Whenever the sniper team is moving from one point on the range to another point, i.e. from the 600-yard line to the 1,000-yard line, or from one position to another on the unknown distance range.
5. Whenever the shooter leaves the rifle for any amount of time, the scope caps go down and the elevation and windage settings go to zero.

These are just the major “must re-index” points that should be tracked. Any other devious methods that the shooters can do to ensure that a sniper always checks and zeroes his data is a good idea. We used to pull tricks on each other by adding another revolution to the windage or elevation data. We would also do it to other teams and sit back and watch as the observer watches for bullet trace and then suddenly looks up, downrange, back through the spotting scope and then back up again. Then he would ask the shooter what the hell happened. Then that observer would look left and right at other observers, and see one of them grinning at him. He knew he’d been had!

In summary on the first shooting exercise, know that this doesn’t have to run once in a course. It is only a range scenario. We scheduled two or three 600-meter events and then evaluated the shooters with videotape and an instructor debriefing. The 600 meter event not only starts the basis for precision shooting of the rifle but the discipline necessary to coordinate the fire of two or more weapons under a single observer. The following major points are the focus of the 600-meter event for the both the shooter and the observer:

- Use X5 round groups to get the shooter used to the rifle, the position, and to “neutrally” fire the rifle.
- Use proper after-shot technique and avoid trying to get the gun back on target too fast and inducing error in the system.
- Understand the effects of the high volume muzzle brake and methods for blocking the brakes and minimizing the effects on the shooters.
- Use observer-enforced principles for the shooter including site preparation, weapon preparation, position preparation and sight manipulation.
- Follow the basics on shooter / observer dialogue.
- Make sure the observer backs up the shooter on his elevation and windage settings and other procedures.
- Make sure the observer bases his wind calls on data tables and not previous experience with other rounds of ammunition.

A final note about observers. Previously trained snipers are used to their observer being on their strong side. The spotting scope is placed to look along side the gun or over the shoulder of the shooter depending on the school and philosophy used to train the observer at the time. Large bore rifles with muzzle brakes vent their hot and cold gas out of the vents on both sides of the brake. Some do it up and down also, but they all do it to the side somewhat. There is a major problem with that. An observer is looking right into this blast area when the rifle goes off. What we have done to alleviate this problem is to move the observer behind the shooter. Here are some variations on this theme:

1. Observer is actually located between the shooters legs looking just over the shooter’s left shoulder. This places the line of view in the clean area directly above the muzzle brake.
2. The observer is located well behind and looking just over the top of the shooter’s shoulders or over the top of the head.

The SOTIC instructor cell from 1st Special Forces Group went to the 10th SFG’s sniper match in 1996. My partner and I were using .300 Winchester Magnum rifles. Fort Carson is approximately 5,700 feet above sea level. The air is very thin up there. One of the problems that we encountered was that bullet trace was very thin. When a shooter is located in the traditional location close to the rifle, the disruption of the muzzle blast was enough to completely obliterate the trace of the bullet from the observer’s view. My partner and I were using Motorola Saber II radios with ear microphones and fingerswitches. They were being used just for some evaluation purposes. We were getting ready to shoot the unknown distance match and as he touched off his first round downrange, I instantly couldn’t see trace.

He did hit the first target, but all I saw was disruption. So I grabbed the Swarovski spotting scope and

moved to a spot about 15 feet behind my partner. It was about 1.5 feet above the shooter. Normally, we could not communicate with each other in the traditional methods of voice communication. The Motorola radios gave us the flexibility to continue to shoot and watch trace downrange. I was able see trace very well from that location and index targets and give data to my partner. We cleaned the course of fire using a .300 Win Mag and a 900 meter reverse image zero, ignoring range estimation. Observers, be dynamic in your location and use different methods of communication. Low-watt radios can be used to preclude the danger of radio direction finding.

A point to remember, though. An observer can set his primary spotting scope well behind the rifle, say 15 feet. He then can return to the shooter's side to give him data and crunch the numbers. When the shots are ready to go down, he returns to the primary spotting scope. Once the first shot goes off, whispering is no longer needed. After the first shot goes downrange, the observer can talk normally to the shooters even with ear plugs in place. Whispering is pointless unless you are using suppressed rifles. HTI operators will evaluate the electronic warfare environment and assess the dangers in using low-watt radios to talk to their shooters. As you will learn later, both guns do NOT need to be located directly with the observer. A "base gun" is used to determine corrections to other shooters. There are some serious training requirements needed to coordinate the shooting capability of an HTI team. Most of the rest of these range scenarios are developed with this integration in mind.

Snipers of all sorts are familiar with shooter's logs and their intent. Take a look at this copy of a page from the Shooter's Log for Hard-Target Interdiction. This is the 600 yard or meter sheet. The target depicted is the 600-yard NRA bull's-eye target. This is the sheet that should also be used when zeroing the heavy rifle. If you cannot procure these NRA targets (they can be purchased from the NRA), you can make your own using the dimensions located in Appendix A. This form asks for the MET and ENV data that the observer will use to correct for these conditions.

Traditionally, the shooter keeps this book next to him and records the shots as they occur. For our purposes, it is recommended that the observer keep this book. He can use it to indicate where he thinks rounds impact and then confirm or deny that information when the targets are analyzed. When this form is combined with the precision zero cards in Chapter 5, you have a solid record of all shots fired for the zero and all shots fired for training.

**KNOWN DISTANCE
SHOOT #2 1,000 METERS:
SINGLE SHOOTER WITH OBSERVER
INTEGRATION OF SECOND SHOOTER
INTO TEAM**

This range scenario is fundamentally an extension of the 600-meter shoot. All of the previous principles apply here. For the first and maybe the second 1,000-meter shoot, there still will be a single shooter and observer per team. This is intended to push the

This is a copy of the 600-yard/meter shooter's log. A reproducible copy of this page is in Appendix A.

engagement range incrementally further back. One thousand meters is the longest range that many shooters have ever experienced. Some shooters may encounter a capability “wall” at this range. The 1,000-meter range has a certain mystique in the sniper world. Those four numbers are thrown around more freely than any other figure out there. Promises of guns that can shoot 1/4 MOA at 1,000 meters have been seen here and there. One of my personal pet peeves is the claim of “head shots at 1,000+ meters.” Uh huh, OK. Show me.

As instructors gain experience and knowledge in teaching this concept, they will tailor courses based on their own observations and experiences. That is the beauty of how Americans think. We are never really quite satisfied with what is out there. Snipers especially are curious as to what else there is and how much we can “tweak” what we have. These range scenarios are a baseline of procedures that will train a heavy-class rifle shooter and Hard-Target Interdiction operator. The 1,000-meter event is a wrap up of the introduction and familiarization phase. The operator at this point has fired about 50-75 rounds. That may not sound like much, but remember the pace is slow for a reason. High-round counts DO NOT equal high-quality training. During a standard sniper course or a SOTIC course, round counts will reach as high as 120 rounds in a day for NMC training and 60-80 for long-range grouping drills. The round count is considered high for a 50-round day for a HTI course.

The next phase is the 1,000-meter range scenario. This is the first range at which the observer’s job gets a little bit more complicated. One thousand meters is the first range at which we begin corrections for MET and ENV conditions. There is another factor that drives training time and round counts. This is the training location. Every Army post that I have been on had 1,000-yard known distance ranges. The problem is that the only one that I could shoot a .50-caliber rifle on was Fort Bragg. The Fort Lewis KD ranges were on a smaller impact area and we could not shoot .50-caliber rifles there. The solution was to set up a known distance shoot on the larger impact areas. We would range a target array with the 2-inch theodolite and set up 6-foot bull’s-eye targets in a known distance environment. This requires that the shooters fire their 2 X5 round groups and then move downrange to check their targets. Another option is for a pit crew to sit to one side of the range and then on command go out and mark groups with 3-inch or 6-inch spotters. Clearly, this causes a problem because the very best feedback is shot by shot feedback off the target. Dealing with this problem is a demand for the instructors at the time. If anything it forces the pace to stay nice and slow. There are two sub-scenarios to shooting at 1,000 meters.

Single Gun/Single Observer

This scenario is an extension of the 600-meter scenario. The difference is introducing teams to the procedures for correcting and indexing corrections for MET and ENV conditions. The shot group strings are all 5 round groups with the shooter taking his time. Progress to 3 or 4 groups before rolling over the shooter and observer. The observer should be well practiced in the calculations for the MET and ENV corrections. This minimizes the shooter’s “down” time where he quickly gets bored and tired sitting behind that gun. The observer’s target time for calculating these corrections is 5 minutes. These calculations do not need to be done on every 5-shot group. They should be done when the shooters roll over or when beginning a string after a break or other interruption. This isn’t because the conditions may change over that time, but to get the team practiced in the careful coordination and integration between the shooter and observer on these precise procedures. At this point we are going to deviate a little from concentrating on the marksmanship aspects of the shooting here and concentrate on the Shooter/Observer integration and the steps that take place when setting up for the shots on the KD range. This will include the following steps. These are specific to only one gun and are a bit more complex for multiple guns. Once these procedures are established well on the KD range, they are easily done on the unknown distance range. The KD range only serves as a better platform for grouping and marksmanship practice.



1. Establishing the position.
2. Gathering meteorological data: barometric pressure, air temperature, ammunition temperature and environmental data as well as slant range to the target (if any).
3. Establishing the range to the target.
4. Beginning calculations and transmitting elevation and windage data to the gun. Shooter sets this data on the gun.
5. Getting final windage data and transmit to shooter.
6. Post-shot activity. Watch for the trace of the shot and calculate any correction necessary and transmit to the shooter.
7. End of group or end of mission.

We have already established the position and gathered pertinent data. The observer now enters the data on the calform and begins his calculations. In this case as he determines the data corrections he passes them to the shooter to put on the gun. It is assumed that these calculations are done in advance of identifying a target. Even though this is a KD range event, it is treated as if there is no target. These essentially are rehearsals for live fire scenarios. For the purposes of this discussion, the conditions are as follows:

- Range to target: 1,000 meters
- Slant angle: none
- Barometric pressure: 28.85 In. Hg
- Air temperature: 100 degrees F.
- Ammunition temperature: 100 degrees F.

Here is a depiction of an exchange on the range between the observer and the shooter. The observer has gathered his data and has solutions for the MET and ENV conditions and is passing that data to the shooter, who repeats it back and put the data on the gun. In Chapter 6 it is recommended that the corrections be totalled and determined by the observer, then passed to the shooter all at one time. In this case, we are doing it as they are calculated point by point. It's good training for the shooter, and in high-stress scenarios serves as a sanity check for the shooter to hear the observer's numbers. The shooter might catch something that doesn't make sense.

<u>OBSERVER</u>	<u>SHOOTER</u>
" TARGET Bullseye Target #16"	" IDENTIFIED "
" ELEVATION , Index 36.75"	" ELEVATION , Index 36.75"
" CORRECTION FOR PRESSURE , Drop one half minute of angle"	" CORRECTION FOR PRESSURE , drop one half minutes"
" CORRECTION FOR AIR TEMP. Drop one point five minute of angle."	" CORRECTION FOR AIR TEMP. Drop one point five minutes"
" CORRECTION FOR AMMO TEMP. Drop two minutes of angle."	" CORRECTION FOR AMMO TEMP. Drop two minutes of angle."
At this point the observer determines what the elevation setting should be by subtracting the corrections from the True Range elevation setting of 36.75. The final setting should be 32.75 MOA after subtracting 4.00 MOA for corrections.	
" GUN 1 , Say Current Elevation Setting"	" Current Elevation 32.75 Minutes "
" SPIN DRIFT , Left one half minute of angle"	" SPIN DRIFT , left one half minute"
" STANDBY FOR WINDS "	
" HOLD " CENTER " Observer checks his shooter and watches for trace and impact. Switch back and forth on other shots watching the shooter actions and the flight of the bullet.	" READY " <i>Shooter is on target with elevation indexed to 32.75 and windage at 1.50 for spindrift.</i>
	BANG , The shot goes off and the shooter executes follow through and re-acquires the target.

OK, that takes us through the new stuff involving the single gun/observer scenario. We have introduced the corrections for MET and ENV conditions to the shooter/observer dialogue. This brings us to the next phase of introduction to HTI training methods.

Multiple Guns/Single Observer Team Range Procedures

Multiple guns give the hard-target team more flexibility on the target and also allow them to hit a target faster and harder and leave the area that much quicker. It also allows them to fix those mechanical problems that crop up. It would be a disaster to begin an engagement and have the one and only heavy rifle go down after the first shot. It happens. Four-man HTI teams have the capability of having up to 3 guns firing at any one time or in a multiple target engagement. At a minimum, any target worthy of the attention of an HTI team is also worth the effort of carrying at least two guns to that target. Target complexes as you will see in Chapter 11, "Target Analysis," will always have something else of value or targets of opportunity. A mobile surface to surface missile site (read SCUD) may be accompanied by a ZSU-23 system, that just happens to make an excellent sniper suppression weapons platform. A few Greentip shots through the turret might take that piece of equipment out of action. That's also part of the reason you stand off as far as possible—low signature to the enemy.

The only difference between single-gun and multiple-gun engagements is the control procedures so that the shooters don't get confused by the observer's directions.

1. Establish the position and identify a base gun. This is the gun that the observer will line himself up on.

The observer must select one gun to observe the trace of the shot. He will have to assume that all other guns are shooting to the same point or to their specified targets on the target complex.

2. Gather MET data: barometric pressure, air temperature, ammunition temperature and ENV data as well as slant range to the target (if any).
3. Establish the range to the target(s). Observer is building a range card at this point. He identifies different targets for the guns and their priority of fire.
4. Fill in the targets assigned to guns on a field sketch/range card. It is recommended that the observer make a sketch of the target. Better yet, depending on the target intelligence, a photograph should be used. The observer then identifies multiple targets on that target complex (See Chapter 11 for definitions). He then assigns his guns to those targets in the priority of their engagement. This can be done on a KD range also. During this 1,000-meter exercise the observer should not shift the guns around as the shooters and observer are using this exercise to begin firing rounds on command simultaneously.
5. Begin the dialogue by assigning the targets to the individual guns under his control. For the purposes of the 1,000-meter KD shoot, he simply assigns a different target board to the guns. For example:

"TARGETS"
 "GUN 1, Target board #10"
 "GUN 2, Target board #11"
 "GUN 3, Target board #12"
 "Stand by"

6. Begin calculations and transmitting elevation and windage data to the guns. The observer must determine if the range to all the targets is the same. If these ranges are the same, the calculation process is simple; if not, he must determine if the differences in these ranges are significant enough to recalculate the firing data for each gun. The observer, however, is encouraged to "simulate" different ranges by simply adding 10 meters to one of the ranges and then calculating different data for each gun and observing the changes of impact on the targets.
7. Calculate corrections for MET and ENV conditions. Once obtained, transmit the data to the guns. The observer must warn the guns if the data he is giving them is for all guns or for the individual guns. He sets this up by saying:

"ELEVATION DATA, All guns" or
 "ELEVATION DATA, Gun 1 or Gun 2, etc."

8. Obtain and calculate dominant wind data and transmit to guns. This is the time to add in the spin drift correction. These two numbers are combined and the total is given to the guns. Remember that this is the wind condition that the observer feels is the most dominant condition. One method is to give the shooters a setting for a certain wind speed and then give firing commands when that condition is repeated or if it still exists when it is time to shoot. It goes something like this:

"ALL GUNS, Left 10.00 minutes"
 "STAND BY"

9. Final wind call and firing commands. The observer waits for his dominant wind condition to return and gives firing command sequence to his shooters. There are a couple of special commands here to identify if the procedure is a battery fire or individual fire event. (Battery fire is used when all guns are given their elevation and dominant windage settings and then on command, all guns fire simultaneously. Individual fire is used when all guns are given their elevation and windage settings and the observer gives firing commands to individual guns as he sees necessary. This may be done when one gun is given a specific target and the others are backup guns only, or are standing by for targets of opportunity.)

TRAINING THE HARD-TARGET INTERDICTION OPERATOR

“BATTERY FIRE, Hold center, READY, READY, READY, FIRE” or
“GUN 1, Hold center, READY, READY, READY, FIRE”
“GUN 2 AND 3, Hold center, READY, READY, READY, FIRE”

10. Post-shot activity. Watch for the trace of the shot and calculate any correction necessary and transmit to the guns.
11. End of group or end of mission.

The key point to remember in this scenario is that you are training two or more shooters to get used to shooting in close proximity to each other and maintain precision in the shooting. Additionally, the shooters are getting used to shooting on command. With normal sniping, the observer gives the shooter a wind call and the shooter fires when he is ready and comfortable (within reason). When guns are in close proximity to each other, they must go off simultaneously or the blast from one gun will disturb the other guns to his left or right. When all guns are fired at the same time, the effects are negated for the most part. The distance between the guns on the line is about 2-3 meters. Following is an example of a fire mission dialogue between an observer and two shooters on the same gun team.

OBSERVER

“TARGETS,” Gun 1, Target Board #10, Gun 2, Target Board #11, Stand by”

“ELEVATION DATA, All guns, Index 36.75”

“CORRECTION FOR PRESSURE, Drop one half MOA”

“CORRECTION FOR AIR TEMP, Drop one point five MOA.”

“CORRECTION FOR AMMO TEMP, Drop two MOA.”
At this point the observer determines what the elevation setting should be by subtracting the corrections from the True Range elevation setting of 36.75. The final setting should be 32.75 MOA after subtracting 4.00 MOA for corrections.

“BOTH GUNS, Say current elevation setting”

“BOTH GUNS, Left 10.00 minutes, Stand by”

“BATTERY FIRE, BATTERY FIRE, Hold Center, READY, READY, READY, FIRE!”

SHOOTER (S)

“GUN 1, Identified”

“GUN2, Identified”

“GUN 1, Elevation 36.75”

“GUN 2, Elevation 36.75”

“GUN 1, Correction for pressure, drop one half minute.”

“GUN 2, Correction for pressure, drop one half minute.”

“GUN 1, CORRECTION FOR AIR TEMP, Drop one point five MOA.”

“GUN 2, CORRECTION FOR AIR TEMP, Drop one point five MOA.”

“GUN 1, CORRECTION FOR AMMO TEMP, Drop two MOA.”

“GUN 2, CORRECTION FOR AMMO TEMP, Drop two MOA.”

“GUN 1, Elevation 32.75”

“GUN 2, Elevation 32.75”

“GUN 1, Left 10.00 Minutes”

“GUN 2, Left 10.00 Minutes”

Once both shooters receive their dominant wind corrections, they do not say another word in acknowledgement. Talking disturbs the lay of the gun. Once they hear the “BATTERY FIRE” commands, they know that will hear “READY, READY, READY, FIRE.”

It is important to note the level of control and detail between the observer and his guns. The observer gives instructions and data and the shooters acknowledge that information gun by gun and piece by piece. Everything is repeated back to the observer so HE knows that all guns are on the same sheet of music and are on their specified targets.

Remember that the key exercise in the 1,000-meter multiple-gun scenario is to get the shooters in the HTI team used to simultaneous fire in close proximity to each other. The team evaluates their effectiveness by analyzing the groups on the targets for each of the shooters. If possible, the targets should be on a KD range where each individual shot can be marked, or the group as a whole can be marked. It is interesting to note the effect of a bad battery fire procedure when three guns go off at different times. The group is affected by this.

There will be some argument out there that this cannot be done. Our experience is that shooters can be isolated within their sphere. Something that appears to make a difference is electronic hearing muffs. The Peltor Tactical headphones are the ones that we used. The spinoff gain from using these is that instructors can listen to the students when they mumble to themselves. This reveals some stress and can provide insight to the instructor when there is a problem. When students are shooting on a range where there is so much noise, they tend to talk to themselves, thinking that no one will be able to hear them. The 1,000 meter integration exercise can be done as many times as deemed necessary. We found that it takes about 4-5 50-round sessions until a multiple gun HTI team can fire precise groups while being in close proximity to each other.

A note for the instructor: Inevitably, a team will fire a "string" of groups (groups fired when 2 or more guns are shooting groups in battery-fire mode) and one of the groups will fall apart in the middle of the group. This is going to happen. The tendency in the past was to analyze what ails the individual shooter. In battery fire procedures, also analyze if the timing of shooting may be throwing off the shooter. Check to see if his position is falling apart and if he is muscling the gun to keep up with the rest of the team. The observer should control this, but sometimes gets caught up in the excitement of the event. When shooters are firing battery fire on reactive targets, the effects are spectacular. Shooters and observers get excited fast, and then just as fast get puzzled because confidence gets too high and someone blows a shot. I have seen this happen time and time again. Stay on top of the teams and don't let them get too excited. On the other hand, some celebrating should be allowed when a 3-gun team makes simultaneous hits at 2 MOA on a target 1,800 meters away. It is awesome. Once an HTI team can prove that its shooters can fire groups on individual targets while firing in battery fire, it's time to step up the heat. It is also important to periodically schedule shoots with individual guns and a single observer. Sort of a traditional training period where it's more personal and less stressful. Multiple gun battery fire is a stressful event. It's noisy and confusing and happens fast. Instructors shouldn't overanalyze errors. Sometimes they just happen and will correct themselves. Stay on the observers and check their data. This will seem familiar to anyone who was a mortarman or in artillery. It is now time to summarize where we are to this point in the range scenarios:

- **The 600 meter range scenario.** We used this scenario to introduce the shooter to precision fire with the heavy rifles. The emphasis was on developing the grouping capability of the individual shooter. The shooter's emphasis on developing his grouping capability is to "neutrally" shoot the gun and execute good after-shot procedures. Avoiding muscling the gun and relying on isolating the rifle from the shooter's inputs are paramount in this scenario. The shooter concentrates on his sight manipulation procedures. The observer will introduce games into this by trying to catch the shooter "slacking" by adding a turn or two on the elevation and windage knob when the shooter is away from his system and has failed to "zero" his data. The observer's main job was to begin dialogue and enforce the procedures in dialogue. Through X5 round groups, the shooter and observer developed an integrated dialogue that resulted in precise groups at a short range where ENV and MET conditions did not interfere with the basic learning process. The observer should move his spotting scope or theodolite, if he has one, around trying to find the best position to observe trace and remain tactical at the same time.

- **The 1,000-meter range scenarios.** Initially, the objective of this exercise was to push the range of the targets back and to challenge the observer / shooter combination with more difficult wind conditions. This is also the first range at which the observer must determine and correct for MET and ENV conditions. The shooter/observer dialogue is made a bit more complicated by adding these corrections to the dialogue between the two. That dialogue is a precise language used to transmit critical engagement data that is absolutely essential to successful extreme range shooting. The second part of the 1,000-meter scenario is to introduce a second and even a third gun to the team under a single observer. This further complicates the dialogue between observer and shooter. The observer lines up on his base gun and works off that gun. The integration of multiple guns into the system assures that errors sensed by the base gun are also happening to the other guns. This is for errors in wind and other NON-SHOOTER functions. The occasional bad shot by one of the other non-base guns is going to have to be accepted as a common occurrence. The individual guns in the team engage their own known-distance targets. This is done to evaluate the individual's effectiveness at grouping when firing in close proximity to another gun. This exercise develops the team's capability in this.

KNOWN DISTANCE SHOOT #3

THE "MAXIMUM PERFORMANCE ENVELOPE" (MPE) RANGE SCENARIO 1400+ METERS

Maximum Performance Envelope (MPE) is the term to describe shooting at the range where the bullet is nearly at transonic or subsonic velocities as it approaches the target. Remember that each different .50-caliber cartridge has a different range at which that bullet goes subsonic under standard atmospheric conditions (SAC). The velocity of sound under SAC is 1,125 fps. A bullet is no longer breaking the sound barrier once it has slowed down to 1,125 fps. Each of the different cartridge's burnout ranges are listed below:

- Mark 211, Mod-0 = 1,400 meters
- M8 API and M33 Ball = 1,400 meters
- M20 APIT = 1,450 meters
- M-903 SLAP = Supersonic past 2,500 meters

It is true that conditions at any one place on the earth are almost never SAC. If they are, it doesn't last. The barometric pressure and air temperature is always fluctuating up and down. At Fort Lewis, the elevation above sea level was only 260 feet and the barometric pressure was well above standard at 30.10 or more 80 percent of the time. So the pressure was higher there. The purpose of the MPE-range scenario is to set the guns at a range where the bullet is going supersonic all the way to the target most of the time. For example, if you are shooting at a range on Fort Lewis, you would set the targets right at 1,400 meters with another set of targets at 1,300 meters. The purpose of this exercise is to group the HTI teams at a range where the bullet "might" go subsonic at or near the target. The purpose of having two target arrays is to have one that might result in a subsonic shot and one that is close enough to get good supersonic shots on targets.

The natural purpose beyond extending the range and training of the HTI team is to intentionally encounter supersonic burnout. By having a target at a long range and one at a slightly shorter range (100-200 meters) the team can shoot long range when the observer has determined that the bullet will go transonic before that long range target. The benefit is to experience bullet by bullet the effects on accuracy of having a bullet go subsonic before the target. Then the team can shift fire at the short-range target to regain the accuracy expected when the bullet is supersonic all the way to the target. The differences on the target are quite surprising and put to bed some of the arguments of shooting easily past 2,000 meters.

If the long-range target is marginally within supersonic range early in the shoot, say in the morning, there is a spinoff benefit of this exercise. As the temperature warms up, or the barometric pressure drops, that long

range target may slide into the supersonic envelope of the bullet. Lower pressures and higher temperatures will do this. Another way to pick up range is to increase the muzzle velocity of the bullet. This is done by warming up the ammunition. More on this in Chapter 9.

The other way to place a target at the burnout range is to calculate the corrections for the MET and ENV conditions based on the above listed ranges for the different ammunition (Mark 211, Mod-0 = 1,400 meters). Then using the Page 3 of the calcfom (Final Targeting Data) you can determine mathematically where the bullet will go subsonic under the current range conditions. Place the long-range target 100 meters farther than that range and you are making a good simulation for MPE shooting. The short-range target is placed 100 meters closer than the supersonic burnout range. You have bracketed the precise transonic range of the bullet under real range conditions. As MET conditions change, the observer must track any corrections necessary and adjust targets as needed. Something that has never been determined is if the different types of bullets used in the .50-caliber cartridges act differently in the transonic range. Theoretically speaking, projectiles with multiple internal components should be disturbed in the transonic disturbance. On the other hand, monolithic bullets (solids) will be much less disturbed by this transition.

There is a second goal in this MPE range scenario. You may have noticed that I said having ONE target at a longer range and ONE at a shorter range. The reason for having only one target is that at this range the shooters will group their multiple guns on the same target. There are several reasons for having multiple guns on one team. Some of these have been mentioned already. Some targets will require multiple impacts to cause damage to them. Missiles cannot sustain much damage and one or two hits are sufficient to render them useless. Communications vans require some more damage and that's where multiple weapons come into play. A three-gun battery fire with explosive-tipped incendiary projectiles will render most targets that can be penetrated. The key is penetrated. Multiple-gun battery fire reduces time on target and team exposure in the target area.

Trainers can develop some good spinoff training using this technique. Push the targets even farther past the supersonic envelope. Set them at 400 meters past that burnout range and observe the results. In Chapter 9 there will be a discussion on the effects of intentionally shooting at extended ranges so that the bullets are subsonic at the target. Some targets are large enough to absorb the loss in accuracy caused by transonic flight. Other targets, however, such as aircraft, have such a light skin that a Mark 211, Mod-0 bullet traveling subsonic WILL NOT detonate upon impacting the target. The standard for tip detonation is impacting 2024 Aluminum .080-inch thick at supersonic velocities. Slower than supersonic, the RDX explosive MAY NOT detonate.

Up to this point, we have progressed through several stages of training on a known distance range. The scenarios have included grouping at short range with a single gun and observer. Then we moved to a longer range (1,000m) that pushed the range of the grouping exercise and introduced additional guns to the team. This was also the first range at which the observer started his calculations for MET and ENV conditions. The shooters were evaluated on individual targets of a known distance. This led to the next stage in the progression of HTI operators. The MPE shoot is the next range scenario in the training. In the MPE shoot a double set of targets is placed downrange. One is set so that the round goes through the target supersonic and the second target is set so that the bullet goes through the target subsonic. This is to give the observer visual feedback on the effects of transonic flight on the bullet. It also introduced the shooters to shifting to another target.

Shooters and observers must begin a rotation every second or third 5-round group. You may even have a shooter sit out a round or two to take a break behind the gun. This training is hard on shooters and observers. It is stressful to crunch numbers and then figure out that you made a calculation incorrectly and three bullets all plow into the ground 75 meters short or long of the target. Don't be surprised that when this happens the shots are spread in a sheaf instead of on a point. The point impacts should occur at the target, not before it or after it.

At this point in the training, the only difference between known and unknown distance technique is in determining the range to the target. Instructors can and should mix these methods up so that HTI teams are constantly challenged. This is a very dynamic sniping technique. To be honest, it is the same as an artillery

TRAINING THE HARD-TARGET INTERDICTION OPERATOR

Subsonic range band:

For example, 1,600 meters under SAC.
Bullets will definitely be going subsonic at this range. Observers determine the loss of accuracy from their shots going subsonic.

Transonic range band:

1,400 meters for Mark 211, Mod-0 under SAC. Targets should be placed at least 100 meters short and long of this range.

Supersonic range band:

Under SAC this may be around 1,200 meters. This is up to the trainer. Shooters should begin the exercise at this range. Group and practice integrated shooting procedures using battery fire.

Elevation data = Mark 211, Mod-0

1,200 meters = 49.25 MOA

1,600 meters = 89.25 MOA

Difference of 40.00 MOA

Shift fire command:

Observer: "Target, left 30 meters, long range."

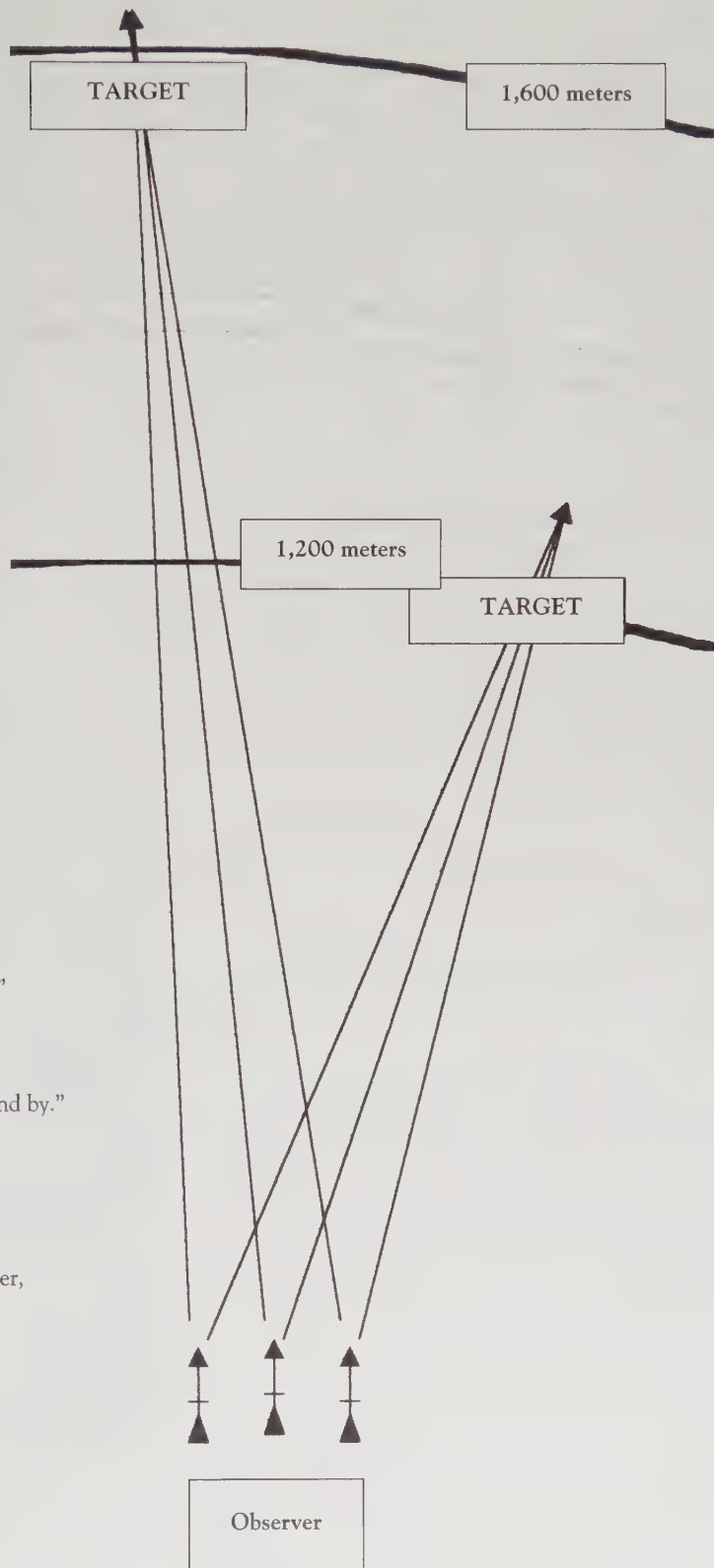
Shooters: "Identified."

Observer: "Elevation, add 40.00 minutes. Stand by."

Shooters: "Elevation, add 40.00 minutes."

Observer: "All guns, left 1.5 minutes."

Observer: "Battery fire, battery fire, hold center, ready, ready, ready, ready, fire!"



fire mission. A target is identified, data is collected and calculated, then this data is transferred to a set of guns and the mission is fired. You can fire multiple guns on a single target or multiple guns on multiple targets. Next we are going to discuss some unknown distance range scenarios and some very dynamic multi-target engagements. At some point in the next phase of training we will add a medium-class gun to suppress soft targets that may be on the target complex. Trainers can add more madness by adding pop-up targets between the HTI team and their target. Security operators can engage these as targets of opportunity while the heavy guns are doing their work on the primary target.

KNOWN DISTANCE SHOOT 4 INTENTIONAL SUBSONIC RANGE SHOOT

As the title of this section says, this known distance shoot is set at a range at which the bullet is definitely traveling subsonic. To determine the subsonic range of the bullet under current conditions, the trainer must determine the range at which the bullet will go subsonic. Here is an example:

- Ammunition - Mark 211, Mod-0
- Slant Angle = 0 degrees
- Barometric Pressure = 31.10 In. Hg
- Air Temperature = 90 degrees
- Ammo Temperature = 70 degrees

Corrections and Determination of Subsonic Range

- Initial range based on subsonic range under standard atmospheric conditions = 1,400 meters or 67.50 MOA elevation.
- Total of all corrections = -2.00 MOA for pressure and air temp: 0 change for slant range and 0 change for ammo temp.
- Final elevation setting = 65.50 MOA. When following the procedures on page 3 of the calcforn you get a gain of 2.00 MOA from the standard atmospheric condition setting of 67.50. This gives you an effective setting for range of 69.50 or an equivalent range of 1,418.18 meters.



HTI operators in front of the target shot at 1,200 meters with Barrett .50-caliber rifles. Note the group size.

Calculated Burnout Range of 1,418.18 Meters

Based on the above true burnout range of 1,418.18 meters, add 200 meters to any range calculated to get a solid subsonic range shoot. In this case, measure off 1,618 or round off to 1,650 or even 1,700 meters. This will give you a solid subsonic range shoot. The purpose of this shoot is to evaluate your weapons and ammunition capabilities in the subsonic range. It will answer some questions. How much accuracy will we lose? How far past transonic flight can we continue to shoot and get at least 3 MOA accuracy?

In this range scenario it is suggested that you use a large target and bull's-eye target types. Each gun should shoot on their own target. After a solid group has formed on the target, go downrange and measure the MOA size of the group and record. You should record the MET and ENV conditions and the size of the group in minutes as compared to a supersonic shoot. It is important to note the deviation. All other procedures remain the same as with other KD shoots.

UNKNOWN DISTANCE SHOOT 1 – SHORT RANGE (600-800 METERS)

The observer's job just became much more complicated in the unknown distance shooting exercise. In Chapter 7 you were shown an entirely new and passive method of range determination. The theodolite is a very fine and precise instrument for determining the range and slant angle to the target. One of the greatest problems for snipers has always been determining an accurate range to the target. One of the greatest "bogus" methods has been the mil relation formula using the Mil Dot reticle. When shooting human targets on the battlefield, targets rarely stand still long enough to accurately mil the target. Also, target definition is a problem. A well-camouflaged target is one with hard-to-define edges, which are so critical to the determination of the value of the mil.

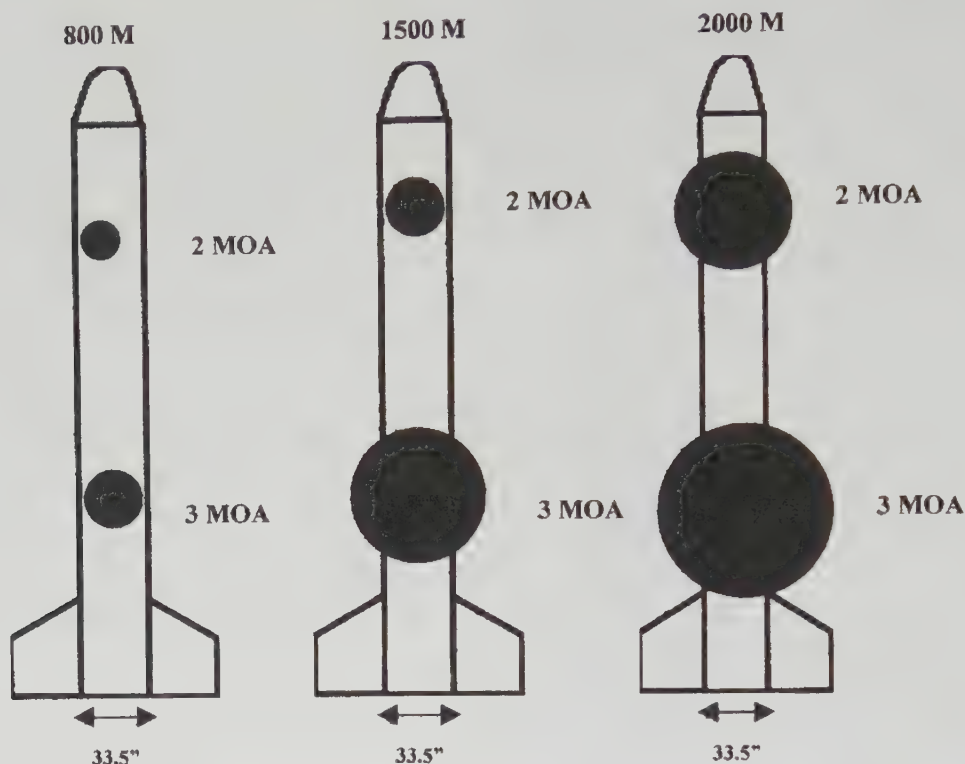
Laser range finders are becoming accurate enough, but as is mentioned in Chapter 7, they are active systems and therefore can be electronically detected on the battlefield and certainly at high-value strategic targets. This all leads up to why we do unknown distance shoots at shorter ranges. Below are targets depicted as SCUD-B missile targets. Remember before that we mentioned that 2 MOA is the desired degree of accuracy on a target? Well that 2 MOA circle gets mighty large at long ranges.

In the beginning of this chapter, it was noted that the training involved in Chapter 5 was for the shooter and the observer. In each of these drills, the shooter is wrung out on his shooting capability and he concentrates on grouping his shots and being precise and quick on the adjustments to the optics and weapon. The observer by far has the most difficult job. Within the HTI element, certain individuals will emerge as better observers and better trigger pullers. This is natural. Although an individual or two may emerge as being better at one subject than another, during training, all personnel must rotate through each position of responsibility. When it comes mission time, put the best people on the job.

Our next stage in the progression of the training program is the unknown distance shoot. The short range (600-800 meter) shoot is designed to allow the observer to train his individual guns on specific targets or parts of targets. If the target is a single item, and he has 3 guns available, the observer may target different parts of the the object for attack. Doing this at short range allows the observer to evaluate each shooter's performance because the 2 MOA arc of precision probably won't overlap each other like they would at longer range. It also allows the shooters practice at shorter range where the wind effects that can be very disheartening at longer range won't exist.

The other element that is added is the element of range determination. As you have read in Chapter 7, there are multiple methods of determining the range to the target. This range determination is critical in many scenarios where a precision attack on a "single point" on a target is essential. A good analogy is the attack on a SCUD missile where that target couldn't sustain any kind of hit. These are easy targets. A more difficult target is a large communications van where you may have knowledge of the specific points of attack from looking at it from the outside, but the point of attack may only be 12 inches across. Therefore a very accurate range is critical.

SCUD-B MISSILES WITH MOA ARCS REPRESENTED ON TARGET



The focus of this range exercise is multiple guns on a single target at an unknown distance. We will mix up the commands a little bit and make them a bit more dynamic. Here is the order of events for an unknown distance event.

1. Establish the position, and identify a base gun. This is the gun that the observer will line himself up on. The observer must select one gun to observe the trace of the shot on. He will have to assume that all other guns are shooting to the same point or to their specified targets on the target complex.
2. Gather MET data; barometric pressure, air temperature, ammunition temperature, and environmental data; slant range to the target (if any).
3. Establish the range to the target(s). Observer is building a range card at this point. He is identifying different targets for the guns and their priority of fire.
4. Observers fill in their targets assigned to guns on a field sketch / range card. Observers will have a sketch or photograph of the point target and specified points of attack on that target. Based on the size of these points of attack, he will know the level of accuracy he must have on his range determination. The smaller the point of attack, the more accurate the range determination.
5. Observer begins the dialogue by assigning the targets to the individual guns under his control. For the purposes of the short-range meter unknown distance shoot, he simply assigns a different target board to the guns. Some targets are a van type target where looking from the outside, all you see is a flat side of a van. The critical point of attack may be up 20 inches and right 40 inches from the leading edge of the van. How do you translate that for the shooter?

**DIVIDE THE INCHES OFFSET (20 or 40) BY THE NUMBER
OF INCHES PER MIL AT THE RANGE DESIRED**

$$800 \text{ meters} / 1 \text{ mil} = 31.49''$$

$$20 \text{ divided by } 31.49 = .635 \text{ mils or } 3/4 \text{ mil up}$$

$$40 \text{ divided by } 31.49 = 1.27 \text{ or } 1 \text{ } 1/4 \text{ mil right from front edge}$$

6. For example, if the target were a communications van with 2 desired points of attack, he may proceed the following way:

“TARGETS”

“GUN 1, Target point of attack, 3/4 mil up and 1 1/4 mil from front edge”

“GUN 2, Target point of attack, 3/4 mil up and 1 1/4 mil from front edge”

“GUN 3, Target point of attack, 1 1/4 mil down and 2 mils from the trailing edge of target”

“Stand by”

7. Begin calculations and transmitting elevation and windage data to the guns. In this instance all of the points of attack are on the same plane which results in the range to the targets being the same. This isn't always the case. While this may seem insignificant, at 800 meters, if the target depth is 25 meters or more and your point of attack is only 20 inches high, you will shoot high or low depending on the depth range of that point target.
8. Calculate corrections for MET and ENV conditions. Once obtained, transmit the data to the guns. In Chapter 6, it is suggested that the observer give the total of all corrections as applied to the elevation setting for the range to target and transmit all corrections as a single elevation setting. The observer must warn the guns if the data he is giving them is for all guns or for the individual guns. He sets this up by saying:

“ELEVATION DATA, All guns, index 25.50 minutes”

or

“ELEVATION DATA, Gun 1 or gun 2, index 25.50 minutes”

“All guns STAND BY”

9. Obtain and calculate dominant wind data and transmit to guns. This is the time to add in the spin drift correction. At shorter ranges (less than 1,000 meters) using the dominant wind technique is not necessary. At these shorter ranges, giving a mil holdoff is sufficient. The spin drift correction is only .25 MOA. That number is too small to add to a mil holdoff as .25 MOA is only .074 mils. A little too tight. In this situation, the wind call will be the pre-firing command. It goes something like this:

“ALL GUNS, Left 3 mils”

“STAND BY”

10. Firing Commands. The observer waits for his dominant wind condition to return and gives firing command sequence to his shooters. There are a couple of special commands here to identify if the procedure is a battery fire or individual fire event.

“BATTERY FIRE, Left 3 mils, READY, READY, READY, FIRE”

or

“GUN 1 and 2, Left 3 mils, READY, READY, READY, FIRE”

“GUN 3, Left 3 mils, READY, READY, READY, FIRE”

11. Post-shot activity. Watch for the trace of the shot and calculate any correction necessary and transmit to the guns.
12. End of group or end of mission.

The short range unknown distance range scenario is intended to introduce the observer to the methods of targeting specific points of attack on his target and assigning those points of attack to a shooter. If it is required he then has to determine the different ranges to different points of attack on that target.

“OBSERVER: GUN 1, Target missile launcher far left, point of attack, bottom launcher box, 4 mils down, 3 mils right from top and left corner of box”

“SHOOTER GUN 1: Identified”

“OBSERVER: GUN 2, Target missile launcher center, point of attack, bottom launcher box, 3 mils down, 2 mils right from top and left corner of box”

“SHOOTER GUN 2: Identified”

“OBSERVER: GUN 3, Target missile launcher far right, point of attack, bottom launcher box, 2 mils down, 1 mil right from top and left corner of box”

“SHOOTER GUN 3: Identified”

“OBSERVER: Stand by” This is followed by any follow-up targets that the observer may want to have each gun shift his sights to. It may also specify how many rounds he wants on each target.

“OBSERVER: All guns, 3 rounds each target, shift fire to generator box on front of launcher trailer, 3 rounds on target, stand by”



“SHOOTERS: Identified” The observer then calculates and transmits the elevation and dominant wind data to the guns.

That wraps up the short-range unknown distance shoot. This brings us into our next realm of training. First a quick note: Any of these scenarios can be modified by an instructor but the important thing to remember is that you **SHOULD NOT** proceed to the next event until the teams have mastered the event they are working on. It may take 3 or 4 turns at the MPE known distance shoot before they are ready for multiple targets and multiple taskings.

UNKNOWN DISTANCE SHOOT 2

THE MAXIMUM PERFORMANCE ENVELOPE (MPE) UNKNOWN DISTANCE SHOOT

This scenario pushes the range of the sniper team to the maximum range at which the bullet will be supersonic all the way to the target. The trainer establishes the positions of the sniper teams and the target. The teams do **NOT** know the distance to the target. This requires that the trainer obtain the MET and ENV conditions and determine the range at which the bullet will begin transonic flight. Example:

- AMMUNITION: Mark 211, Mod-0, supersonic range under SAC = 1,400 meters.
- SLANT ANGLE to target: 0 degrees
- BAROMETRIC PRESSURE: 26.75 In. Hg
- AIR TEMPERATURE: 110 degrees
- AMMO TEMPERATURE: 100 degrees

Corrections and Determination of Subsonic Range

- Initial Range based on subsonic range under SAC = 1,400 meters or 67.50 MOA elevation.
- Total of all corrections = -11.25 MOA for pressure and air temp: 0 change for slant range and -2.00 MOA change for ammo temp.
- Final elevation setting = 54.25 MOA. When following the procedures on page 3 of the calcform you get a gain of 11.25 MOA from the SAC setting of 67.50. This gives you an effective setting for range of 78.75 or an equivalent range of 1,502.32 meters.

After doing these calculations the trainer determines that under the above conditions, the range at which the bullet will begin transonic flight is 1,500+ meters. He wants the bullets to impact targets supersonic but as far out as he can push the range of his guns. The trainer should set his targets at 1,400 meters. This gives him a good envelope for his training and allows for changes in air pressure or the possibility of a temperature drop. Remember that the 2 MOA arc at this range is 31.76 inches for 1,400 meters. A more realistic arc of 3 MOA = 47.64 inches. The point here is that when pushing guns and shooters to their maximum effective range, small errors on the gun end become errors on the target end. At this range, it is recommended that multiple guns be used to engage the same target and then shift guns as a battery to the second or lower priority target. In the first scenario, the short range shoot, multiple guns were used to engage multiple targets at the same time. In this scenario, multiple guns are used to engage points of attack on the same target at the same time.

“OBSERVER: ALL GUNS, Target missile launcher array, warhead section, 4 mils down, from top and lateral spread” (lateral spread means left gun target left section, center gun, center section, right gun, right section of target)

“SHOOTER GUN 1, 2, and 3: Identified”

“OBSERVER: Stand by” This is followed by any follow-up targets that the observer may want to have each gun shift his sights to. It may also specify how many rounds he wants on each target.

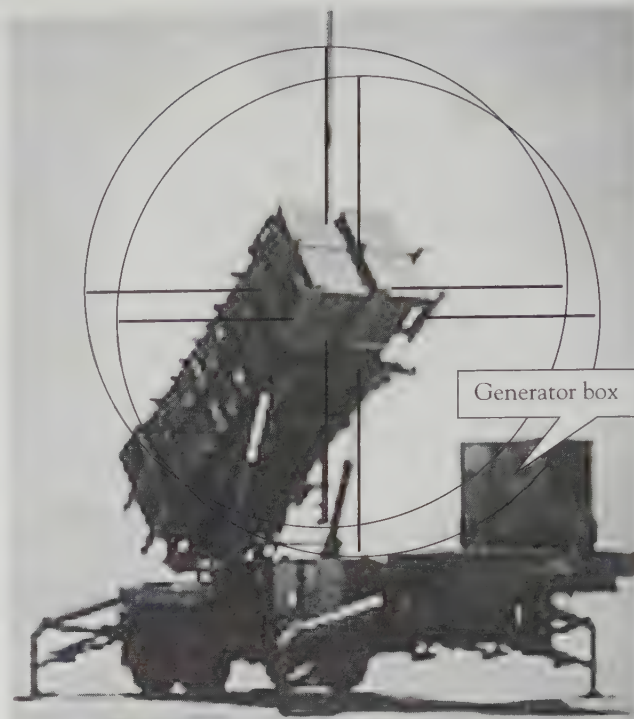
“OBSERVER: All guns, 3 rounds each gun, shift fire to generator box on front of launcher trailer, 3 rounds on target, stand by”

“SHOOTERS: Identified” The observer then calculates and transmits the elevation and dominant wind data to the guns.

“OBSERVER: “ELEVATION DATA, All guns, index 54.25 minutes, stand by”

“SHOOTERS: Index 54.25 minutes”

“OBSERVER: BATTERY FIRE, Left 3 mils, READY, READY, READY, FIRE”



The sniper teams should be starting to mesh pretty well at this point. You have run 5 range scenarios, each as many as 3 or 4 times. Round counts per shooter are around 500-750 rounds. The shooters and observers should be pretty well rounded out with the best people at each position starting to shine. Little differences in how each team will add or take away from their commands appear as they begin to mesh. As long as the important data is transmitted or there isn't any additional chatter added to the dialogue, this is OK. As the teams progress, their chatter will become less and less as they settle into a routine that becomes fast, accurate, and smooth.

You may have noticed that the progression of shooting exercises begins with the KD event at short, MPE, and then subsonic ranges. Then you proceed to the unknown distance shoots at short, MPE and then subsonic ranges. The reason is to expose the teams to different environments, changing dialogues, different targeting scenarios, and fast-changing environments. All of the principles that are written about in the KD shoots apply to the UKD shoots. You can run multiple scenarios multiple times. Start the day off with a 1,000 meter KD shoot, followed by a MPE unknown distance shoot with multiple targets. But we are not through yet.

UNKNOWN DISTANCE SHOOT 3 INTENTIONAL SUBSONIC / UNKNOWN DISTANCE SHOOT

This range scenario places targets at ranges where the bullet is intentionally going subsonic at the target. In the known distance subsonic shoot, you shot at a known distance to experience the differences in accuracy when firing at a target where the bullet is going subsonic. The rounds fired will be less accurate because of turbulence caused by the bullet breaking the sound barrier while slowing down. Remember, this slowing turbulence causes the bullet to pitch and yaw. The results at the target are unpredictable. Different bullets will react to this event in different ways. It is important to note the difference between the different types of ammunition. This event can be long and drawn out as shooters work their way through different types of ammunition.

There are sound tactical reasons for intentionally shooting at subsonic ranges. Provided the bullets are accurate enough to hit a large target, a slow-moving subsonic bullet will not have a “crack” associated with it.

If engaging missile targets and the bullet is not breaking the sound barrier, security personnel may not hear the bullet coming into their area. The size of a 2 MOA arc at 1,600 meters is 36.48 inches and a 3 MOA arc is 54.72 inches. As you can see, the accuracy envelope is getting pretty big. Many shooters have talked about engaging targets at 2,000 meters. OK, at 2,000 meters the 2 MOA arc is 45.52 inches. With that in mind, and given that a 2 MOA arc with a shooter and his rifle are really asking for a lot at 2,000 meters, doesn't the possibility of human kills at that range sound a little ridiculous? I would think so, but it can be done. Refer back to the drawing of the SCUD-B missiles in this chapter and note the size of the 2- and 3-MOA arcs. Both arcs are bigger than the missile body. Even if all things are done perfectly, you have only about a 50 percent chance of hitting that missile target at that range.

Engaging targets in the subsonic range band is best done by attacking targets with battery fire on individual points of attack and then shifting guns or teams onto other targets one by one. This is done by the observer doing one of two methods of fire control. The marksmanship skills at this point are secondary to the observer procedures and fire control methods given to the shooters. Using this method, the observer can determine the effects on the target and shift the gun when the observer is ready. Following are examples of this in action.

“OBSERVER: ALL GUNS, Target Missile Battery Array, Warhead section, center mass of launcher box forward of erector arm.”

“SHOOTER GUN 1, 2 and 3: Identified”

“OBSERVER: Stand by, Prepare to shift on my command to the same point of attack on other launchers in the battery” This is followed by any follow up targets that the observer may want to have each gun shift his sights on that target. It may also specify how many rounds he wants on each target.

“SHOOTER GUN 1, 2 and 3: Identified”

“OBSERVER: “ELEVATION DATA, All guns, Index 88.50 Minutes, Stand by”

“SHOOTER GUN 1, 2 and 3: Index 88.50 Minutes”

“OBSERVER: All guns, Index, Left 10.00 minutes, Stand by”

“SHOOTER GUN 1, 2 and 3: Index Left 10.00 Minutes. . . Ready”

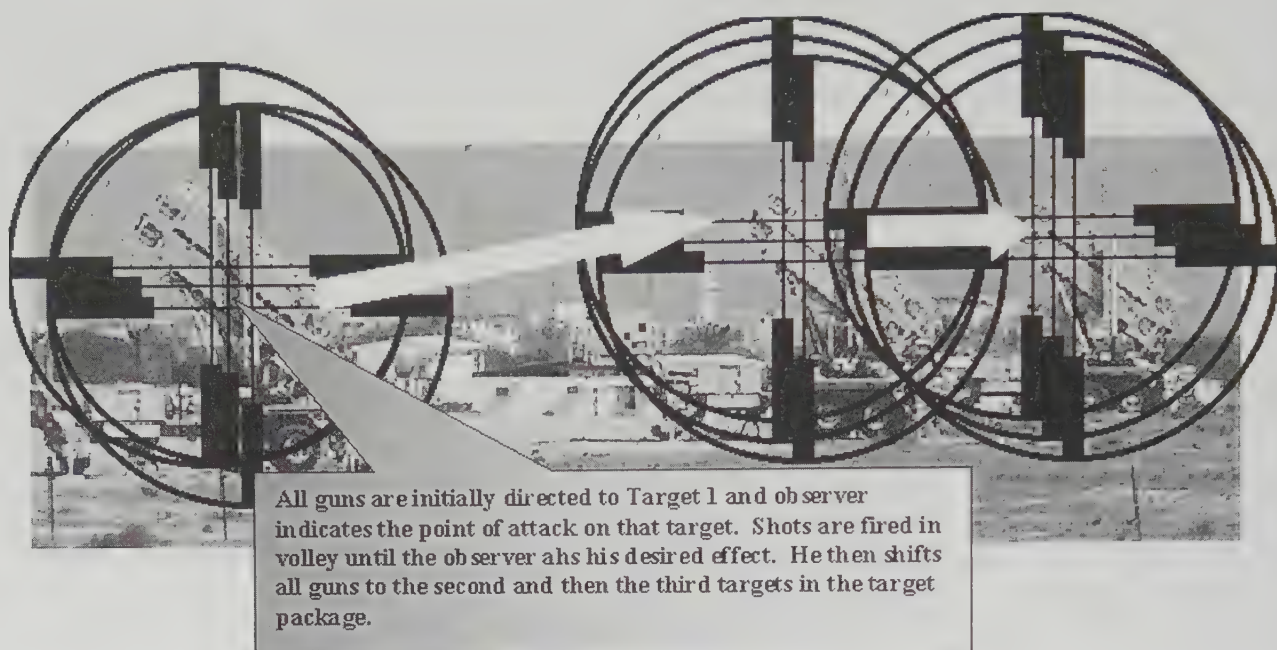
“OBSERVER: BATTERY FIRE, Hold Center, READY, READY, READY, FIRE”

After the observer decides he has the damage he wants on the first target,
he then shifts his guns to the second target:

“OBSERVER: ALL GUNS, Shift Fire, right to second launcher, Warhead section, center mass of launcher box forward of erector arm”

“SHOOTER GUN 1, 2 and 3: Identified”

“OBSERVER: “ELEVATION DATA, All guns, Add 15.00 minutes, and zero your windage, stand by”



“SHOOTER GUN 1, 2 and 3: Add 15.00, windage to zero, Ready”

“OBSERVER: All guns, Index, Left 8.00 minutes, Stand by”

“SHOOTER GUN 1, 2 and 3: Index Left 8.00 Minutes . . . Ready”

“OBSERVER: BATTERY FIRE, Hold Center, READY, READY, READY, FIRE”

The observer watches impacts on the target and gives new windage calls as necessary. Once he has the desired effect on the target he shifts fire to the final missile launcher in the battery using the same procedures as above. At any point in the mission, he may have one gun shift fire to another part of that target or something else that he sees as a threat. In this example, the observer identifies a threat on the first launcher that he must deal with. He is going to shift two guns back to the first target and deal with that threat. Example:

“OBSERVER: GUNS 2 and 3, Shift Fire to first launcher, Immediate Suppression, BTR-50 with troops, Gun 1, Hold Fire, Stand by”

“SHOOTERS 2 and 3: Identified”

“OBSERVER: “ELEVATION DATA, GUN 2 and 3, drop 30.00 Minutes, and zero your windage, Stand by”

“SHOOTER GUN 2 and 3: Drop 30.00 minutes, windage to zero, Ready”

“OBSERVER: Guns 2 and 3, Hold 2 mils Left, Stand-by”

“SHOOTER GUN 2 and 3: Ready”

“OBSERVER: BATTERY FIRE, 2 mils Left, READY, READY, READY, FIRE”

We have discussed all of known distance and unknown distance shooting scenarios that are the basics to bring a “heavy” shooter up to speed to operate on a Hard-Target Interdiction team. We discussed seven different known and unknown distance shoots. We also discussed the different dialogues and some different twists on procedures. These are only the beginnings and each team will operate a slightly different way. Suppressed weapons add a different capability to the team and some other considerations come into play with these devices. Those are covered in more detail in Chapter 9. Observers have a very difficult job and have a lot to control on a mission. We have only discussed the training of a single 4-man element (or whatever the operators want to use as a team basis). Now we move into another realm.

HARD-TARGET INTERDICTION: NIGHT OPERATIONS SCENARIOS

Night Hard-Target Interdiction operations are a much more difficult operation than the conventional sniper would encounter. Just in terms of equipment weight, the HTI team is faced with formidable problems. Hard targets are usually of very high strategic value, yet the human factor on target ensures that some action will be taken. Laser-guided bombs can’t see through the clouds yet, and the new GPS-guided weapons are fairly new and are now only being proven in Iraq. The human element means that any damage-rendering weapon can be stopped up until the last second, and collateral damage is very, very minimal when a .50-caliber bullet misses. A 1,000 pound bomb misses and many people still may die. Another problem with using aircraft is that you generally have to have air superiority for the kind of freehand attacking that the coalition had over Iraq in Desert Storm. Special Operations are best done at night.

Much money goes into giving our U.S. Special Operations the capability to fight at night. Until recently, however, the night sniper capability has been very weak. Most NVDs were designed for other weapons and adapted to sniper weapons systems. Only two systems of late were designed for sniper use. These are the KN-200 and KN-250 SIMRAD sight and the AN/PVS-10 Day/Night sight by Litton. Let’s review the basic rules for zeroing the sights at night:

1. Make a thorough systems check of the rifle, the scope base, and the night vision sight before beginning the zero process.
2. Don’t do anything different at night in preparation for shooting
3. Record all of the ENV and MET conditions and determine the MOA difference from SAC.
4. Determine the operational environment you are going to operate in, if possible. This section is copied word for word from Chapter 6; it is worth reviewing in whole. For most systems when shooting at night, it is recommended that you zero your rifle with night sights at a certain range and don’t mess with the adjustments at all. This is not necessarily true with sights like the AN/PVS-10 Day/Night sight. Even sights with BDCs or sights like the SIMRAD, it is faster to use a Point Blank Zero or a Reverse Image Zero. At night, the shooter is more likely to see a target first. In any case, the dialogue between a shooter and the observer is much more difficult at night. Many times the sniper will be his own observer at night. If your mission analysis shows that terrain will allow only shots under 500 meters, use a 500 meter Reverse Image Zero. See Chapter 9 for more information. Bottom line: if you are going to shoot 500 meters, then zero at 500 meters.
5. Use only one type of ammunition for shooting at night and zero with that ammunition.
6. When zeroing with a totally new sight or one that you have not used before, don’t waste your time by starting to zero at long range.

7. Carefully prepare your shooting position.
8. Be precise about your range to target.
9. Have good communications with the target man on YOUR target.
10. Record all data precisely and religiously. It may be a pain in the butt, but fill in the information in the zero cards. Some time down the road (maybe a long time, but it will come) you will wish that you did just that. Any little nuance may make a difference between life and death. Record everything!

Trainer Tips for Night Zero and Night Live Fire

These are some lessons learned that apply to range and combat operations at night for sniper and HTI missions. They were gathered over a period of 12 years or so. Some of these points were problems that we encountered time and time again, and some were ones that popped up only one time—one very big time.

- Allow plenty of time for a zero shoot. This process can take more than one night session. We planned for three night periods for the zero process. Since the teams won't be used to working at night, they will become tired and distracted easily. Don't push for an 8 hour day when they are worthless at 6.
- Each team needs enough white light to keep track of stuff. One of the biggest time eaters on the range at night is trying to find something. Every operator should have some form of white light. This may sound fundamental and you would think that everyone would have a light, but it just doesn't happen that way. This includes personnel operating the targets.
- If possible, have dedicated target operators. This keeps the teams from having to do an additional "line rollover" where team have pit time or target time. They remain dedicated to the effort of shooting and observing.
- Ensure that each team has all they need before the light goes away. You would be surprised at how many operators forget batteries, wrenches, and data sheets or can't find them when it's time. Make sure that it's organized to the point of having a packing list that they check off. There is a lot of material that the operators need on a range. A checklist is a good way to make sure that they have it.
- Instructors enforce that each team is carefully recording their data. This means their record keeping on the zero sheets and the each team is using the same baseline ammunition for their weapons. Check and make sure that each team is on the right elevation table.
- Instructors have NVDs to check the shooting positions and that team members are doing their stuff the same way they would do them during the day. Procedures should remain the same. Some changes will occur as operators learn to mark specific pieces of equipment with luminous tape and other little quirks that will help them do their job at night. Some of these tips are listed later in the chapter.
- Communications. Each firing team should have direct communications between them and their target operator. This gives better target feedback than relayed information between a "pit boss" and a "line boss." Because of the lower resolution of night sights versus day sights, using spotters may not work. The target operators will have to tell the shooters where their impacts were. This is of course on paper targets. On steel targets, when using Greentip or API ammunition, the report will tell the observer about the impact.
- Target Illumination. This may seem counter to the philosophy of shooting at night—illuminating the target doesn't seem to make sense. Here's the counter to that. Setting up a night shoot requires more than normal effort. Just because the operators are already pushing a 24-or-more-hour day makes the effort that much harder. To get all the way to the range, set it up, and then declare it a non-starter because you can't see the target clearly enough at 800 meters is not a reason to stop training. The biggest problem with shooting at night (besides target visibility) is familiarity with the equipment, mechanical problems that arise from weak night sights or bad weapons/sight interfaces, or system failures. Put some infrared illumination on that target so that the shooters can see it clearly enough to shoot. At the least the shooters will be able to check their weapons' zero repeat capability when switching from day to night

optics. This changing over process is one of the biggest problems. Also, illuminating the target gives the shooter the confidence that he needs to engage the targets successfully. Take away the things that interfere with precision, when you can control that situation.

NVD SHOOT 1 600 METERS, GROUPING AND ZERO REPEAT CHECK

The natural progression of training dictates that once the HTI teams have mastered daytime shooting, they proceed into night operations. After a review of the rules for zeroing at night and some of the tips listed above, we'll move into the first suggested scenario. It is assumed that the last time the shooters fired their rifles at night was when they were zeroed. At the end of that night shoot, the night sight systems were removed and the day scopes replaced. When conducting a night shoot arrive early enough to ensure that the day optics zero is still correct. This repeat check is an ongoing process. It must be done religiously to wring out any errors in zero repeat that may occur. With this in mind, have your shooters re-check their daytime zeros at 600 meters and, once confirmed, record any anomalies, remove the day scope, and install the night vision sight.

The suggested events that should occur during this 600-meter night shoot are as follows:

1. Daylight Zero check of the daytime optics. This is done to establish the fact that the rifle with its day optics are OK. It wouldn't do any good to remove the day sight, install the night sight and then wonder why the gun won't group or hold the zero when the problem is in the gun itself. Establish the function of the weapon in the daytime before complicating things at night.
2. Install Night Optics and do a zero check. You are at this point doing a repeatability check of the night sight's ability to hold the zero that you set on it earlier. Remember to check for any drastic changes in ENV and MET conditions. The one factor that you may have to account for is ammunition temperature.



Instructor's weapon used to designate high priority targets at night—an M995 to see the targets and a GCLP to put a laser mark on the target for the HTI teams.

This is often overlooked by trained operators. They will check the air pressure and air temperature, find them acceptable enough to not have to correct for and then forget that the velocity is lower because of ammo temperature. Check the ammo temp.

3. Conduct the planned scenario for the 600 meter night shoot. As suggested above, this event is a single gun and single observer event. As this is done a couple of times, the trainer may decide to add guns to the team or go to a 3 gun element. The training may be advanced where the team is ready, but the conditions don't allow for long range shooting. Tailor it as needed. Listed below are a suggested series of goals that should be accomplished for this short range night shoot.

- Work out the dialogue that may be specific to night operations shooting.
 - Shooters should iron out methods to verify visually the "indexed" settings that they are putting on the gun.
 - Observers should work out a method to double check the shooters' data.
 - Religiously record all data (especially important is shot-to-shot impact records).
 - Periodically, perform a zero repeatability check. As the gun heats and and cools down this may change the way the rifle repeats zero when installing or removing the night vision sight.
 - Record total battery time and determine that night system's best operational battery life. This is critical as extra batteries mean extra weight. It all adds up. Be scientific in your methodology, don't just guess and be satisfied with that.
 - Record your High Contrast Visual Identification Capability (HC-VIC) with your night sight. Have a number board about a foot in height with a 9-inch number painted on it. Use contrasting colors (black on white) and record under what percentage of illumination you can clearly see that number. Record the changes that occur as the percentage of illumination changes. Also record the position of that illumination when the source is the moon or other low-level ambient light.
 - Record your Low Contrast Vision Identification Capability (LC-VIC). This can be done by dressing a dummy in BDU's or a neutral-pattern clothing and standing that next to the target and recording your ability to see this at this range under the same rules in the above checklist item.
 - Power down, remove the batteries and replace the night sight with the day sight. If possible, recheck your zero if it is getting light enough to do this. Operationally, it is not good to have the daysight gun NOT ready to go.
4. Hotwash. After the training is finished, get the teams together over some hot coffee and talk about any problems that each individual may encounter. These hotwashes frequently bring up problems that other shooters encounter. A group attack on these problems usually irons them out post haste.

This shooting scenario should be a single gun and single observer event. Essentially, this is the same scenario as the Known Distance Shoot #1 – 600 meters. Once all shooters have checked their day zeros and are satisfied that they are sound, have the shooters install or remove their day scopes and replace them with the night sights. For those fortunate enough to have the AN/PVS-10, their life is much easier. However, until that sight becomes more available, most shooters are using the SIMRAD or total replacement sight like the AN/PVS-4, 5, M-995 Night Ranger or other sight.



Night Vision Device boresight kit. Has NVD safe internal lighting with collimator grid.

If there is a combination of different sights from different units, each individual must decide the engagement technique that they will use. The following combinations are possible:

1. **Dedicated Systems (AN/PVS-4, AN/TVS-5, M-995 Night Ranger, etc.)** These sights have no compensators or elevation knobs that allow the operator to index a new range at which to shoot the rifles. If you zeroed the guns at this range, you can still continue to operate by shooting groups and continuing the evaluation process of how the sight repeats zero and holds its zero as shots are fired. Six-hundred meters is a good range at which to maintain a zero on these guns. When you zero at 600 meters, leave the night sight at this zero. Another option is to zero at 600 meters, practice grouping at this range and see if you can push out to 1,000 meters. While it is not likely due to target resolution, you may be able to push the night range farther by illuminating the target with IR laser illuminators or IR flares. Not too passive, though.
2. **Piggyback Night Vision Sights.** These are the SIMRAD KN-200 and KN-250 night sights. These are the most common in special operations right now. The other version of these sights is the NADS-850. Basically it is the same as the SIMRAD sight but is purported to be more rugged and more repeatable. Since these sights use the standard adjustments for windage and elevation that are on the day scope, they can be pushed out to range where the only limiting factor is target resolution. In the 600 night vision shoot, the purpose of the shoot is to determine the repeatability of the zero of the sight when attached to the day scope. Then the drill becomes grouping and fire control at night by the observer.
3. **Combination Day/Night Systems.** The advantage to this very exclusive sight is that there is no replacement necessary. The sight need never be removed. But while other operators are checking their zero repeatability, users of the AN/PVS-10 should do the same zero repeat check. Obviously, these shooters dial the range to the target and shoot center "X" on the target. Their life is much easier than users of the two above systems.

At this point there is no need to go into detail on the shooter's job. Their's is simple. Do as you would do in the daytime and don't push too hard. Many shooters start to feel some "pressure" at night and start getting fidgety behind the gun, and the results show up on the target. The observer's job is a different story. We'll talk about that now.

Night Operations for the Observer

Night sniper operations present a special problem for the observer whose job, among other things, includes major tasks such as reading winds and reading the trace of the shot. We are going to go over some techniques for night sniper operations that apply to all classes of shooters, not just Hard-Target Interdiction operators. We will identify each of the special problem areas and some of the solutions that are suggested. For the civilian shooters out there, none of this will apply because of the technology costs, or maybe that's no problem. Some of these solutions require some technology that is still in the development stage.

Observer Optics

The armed forces has always had pretty decent spotting scopes in the M-49 and the M-144 spotting scopes. There has never been a spotting scope designated for night sniper operations. As previously mentioned, determining winds using downrange data at night is impossible. This is also true for reading the trace of the bullet while in flight to the target. For nighttime spotting of the target area, the observer has many options. His job at night changes a little because he can no longer spot trace. He must make his corrections to the guns based on impacts of the high-explosive rounds. Tracers are not an option. A good choice for observer optics is the M-995 Litton, Generation III night vision sight.

These sights have very high resolution and an inverted "V" aiming point. They also have a Bullet Drop Compensator—unfortunately it is for the 5.56mm round. In the picture on page 261, this is how my gun was

configured as the observer. I used the Litton sight on my M-4 and a Ground Commander's Laser Pointer. More on the use of the pointer later. Since the mission was at night, carrying a separate daytime spotting scope was unnecessary. I used my M-4 as a spotting scope platform.

A major problem occurs at night when determining the range to the target. Night vision capable laser range finders are OK. The atmospheric conditions that affect the accuracy of lasers usually are not present at night. The problem again with lasers is the fact that they are active systems that can be detected by electronic systems. Using the theodolite can be done, but a special adapter must be made to mount a SIMRAD on top of it. Other NVD options include getting screw-in NVDs from the companies that make them and inserting them into the front of the theodolite. More details on night range determination are in Chapter 7.



Special operators with access to the JOS warehouse can get the Litton M-995, upgraded AN/PVS-4s, Aquila night sights, and AN/TVS-5 crew-served weapons sights. Now what do we do with the optics that we have set up? Observers can use weapon-mounted sights or they can mount the NVD to a tripod and be a bit higher up above the guns than he would be with a weapon platform. Having it mounted to a weapon cuts down on your individual load. Range finding is still a problem. There are solutions to that problem in Chapter 7. It is up to the individual operator to decide which method he wishes to use.

Observer/Shooter Target Marking

Have you ever looked at multiple targets under daylight conditions and tried to understand an observer's directions to a specific target? Isn't that a little bit difficult? Well think about that operation at nighttime when the shooters probably have different night vision sights and probably have a different target perspective than the observer. Trying to understand an observer's directions to place a gun on a specific target gets very complex and difficult at night. While it is mentioned above that using a laser to determine the range to a target is ill-advised, using an Infrared laser to illuminate a target may be the only option at night time.

During mission planning or during the final preparation and targeting phase of a mission, the observer will make his best attempt to assign targets as he prioritizes them and sees them. Hopefully, the shooters will see things as he does and clearly see their pre-determined targets. This doesn't mean that things will happen this way. The observer can slave an IR laser marker such as the old LPL-30 or a Ground Commander's Laser Pointer to his night vision sight. This can be done by mounting the laser parallel to the night sight. When the observer sees a target he wants designated or when designating targets gun by gun, he illuminates that target with the laser and talks the gun onto that laser dot. The shooter will clearly see this laser dot and be focused on that target.

The Shoot

With the preliminaries out of the way we can concentrate on the shooting event. The observer checks the shooter position and has basically the same responsibilities that he has outlined earlier in this chapter. Shooters and observers both will note that their shot to shot time is longer because of the blast effects of the

gun not dissipating as fast during the night. This is due to possibly calmer conditions but mostly because of the enhanced night vision optics picking up the light reflecting off of the bits of dust in the air. Shot to shot time is about twice and possibly three times longer at night under calm conditions than during the daytime.

The goal of the 600 meter night shoot is to get the shooter used to his night sight system and to iron out the bugs between the shooter and the observer. The shooter's ability to group is always very important. As mentioned earlier it is recommended that there be only one gun per observer. The 4-man element can break down into a traditional 2-man format for this event. This provides for some more observer training for the shooters. Work 5-round groups with rollovers every 3 to 4 groups. The shooters will tire faster using night vision sights. Their shooting eye will be more strained because of the difference between the naked-eye image and the eye that has been staring at the "green screen" for a while.

NVD SHOOT 2 1,000 METERS, MULTIPLE GUN GROUPING WITH SINGLE OBSERVER

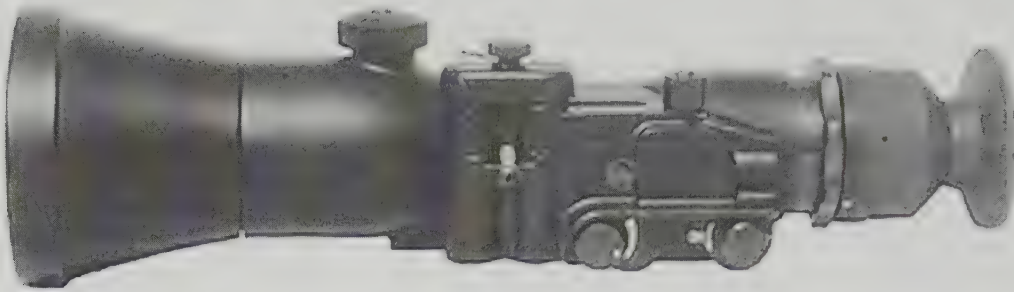
The 1,000-meter night shoot is an extension of the 600-meter event. As with all of the scenarios in this chapter it is intended to make the training a little more challenging for the shooters and the observer. This scenario integrates multiple guns under one observer. All of the rules that were used as guides in the 600 meter shoot apply to this shoot. The 1,000-yard known distance daytime scenario introduced the corrections used for MET and ENV conditions. It is true that shooting at night is a little better as far as lower wind disturbances. Night time also brings its own special little quirks. Snipers everywhere are much more accustomed to daytime operations.

In the U.S. Army, snipers have been left far behind as compared to the rest of the armed forces' abilities to fight at night. The air temperatures drop at night and the barometric pressures will change as drastically as they can during the daytime. Detecting winds and all of the other little disturbances becomes almost impossible at night. This is very true at longer ranges. While you can feel the wind at your position easily enough, detecting downrange wind is extremely difficult unless there is some medium for the wind to move, such as smoke, etc.

Night sniper training may well end as far as a practical range at 1,000 meters due to the systems used for night sights that are currently out there. There are good systems to be had that can allow the sniper to shoot to 1,500 meters or more, but they are on the shelves and NOT in the hands of the operators. This is not exactly true, however, and some very special units have these in hand. They are very expensive and may never see the masses of the military. By the "masses" I'm referring to the "white side" special operations units, not the regular army. The Special Forces Groups, Ranger Battalions, and the Marine Scout Snipers don't have these exotic systems. They may never see them. While the intent of this book is to be used by all trainers and operators, there are systems out there that this author does not know about. Because of this, I will consider these training techniques for the "white" special operations forces units.

The 1,000-meter night shoot will open some eyes as to the difficulties of shooting these systems at night. Many of these concerns are mentioned in the section on the 600-meter shoot. The 1,000 meter KD night shoot only adds the factors of multiple shooters and corrections for MET and ENV factors. This is a good time to identify some of the problems that will occur for the observers and shooters when shooting at 1,000 meters and the longer unknown distance shoots. I will try to identify some of these problems and then offer some solutions.

1. **SHOOTING DEDICATED SYSTEMS (AN/PVS-4, AN/TVS-5, Litton M-995, Aquila, Etc.)** Many snipers that read this book that have access to any night vision sight at all are going to be using dedicated systems. For the most part these systems are adapted from systems that are intended for machine guns or other weapons systems. This is evident because of the lack of a method for indexing windage and elevation settings for anything other than zeroing the sight. Many of them only have a method for



indexing these ranges by a type of reticle pattern inside of this sight. Users of these systems will have to choose a range at which to zero their night sight and leave it at that. For these operators using a single range zero of a very long range (1,100 meters) and then use the Reverse Image Zero method, that is covered in Chapter 9. This can be practiced on known distance ranges as well as unknown distance ranges. The other problem that occurs for dedicated night vision system shooters is indexing corrections for MET and ENV conditions. There is one solution and it's not a very good one—once the observer makes his calculations for MET and ENV conditions, he converts this correction from MOA to raw feet and inches above the target or below the target. The reason that I say this is a bad option is because when using the Reverse Image Zero technique you are aiming at the bottom of a target. While this is usually easier on materiel targets, it is made infinitely more difficult because you are now trying to visually project 13 feet 8 inches below the target to compensate for those MET and ENV conditions.

EXAMPLE: Range = 1,500 meters. Elevation setting = 78.50 MOA uncorrected
 Total corrections for MET and ENV conditions = - 9.25 MOA
 Calculations converted to feet and inches. = 13 feet 8 inches low on the desired point of impact.

The dialogue between the observer and his shooters is a little more simplified with the dedicated systems, however. The problem is that this is very much a compromise method of engagement. At very long ranges where the holdovers and holdunders may easily be 15 feet or more, the odds drop drastically. Under these extreme conditions the team may have no other choice but to move closer to the target. Another option for a team is to use weather intelligence to their favor. If weather intelligence is good enough they can pre-zero their night sights at the best range they can determine based on imagery and then correct for MET and ENV conditions. These corrections can be built into the zero. Once the team gets on the ground they take final readings and make holdovers or holdunders based on the changes from weather intelligence information. These differences are quite likely to be much smaller than when making hold changes based on corrections from standard atmospheric conditions.

2. **PIGGYBACK NIGHT VISION SYSTEMS.** A smaller number of shooters out there have these systems available. The most famous of these of course is the SIMRAD. Notice I said the most popular, not the best system. These systems sit on top of the day optic and basically reflect the intensified image through the day optic. An inherent problem with these systems is that they are designed for use with lower power optics. By the very nature of heavy-class rifles, the scopes used on these are frequently 16X or more. There are also a number of Swarovski 10X and Leupold & Stevens Mark IV, M-1 in 10X. These lower power systems will work better with the piggyback systems. It is important that each and every time this system is put on the day scope the zero repeats the same way every time. Those zero cards at the end of Chapter 5 should be referenced to make sure that the changes (if any) are indexed on the day sight and any changes are recorded. If these systems are working (with cooperating weather conditions) a sniper using this NVD

sight will be able to do grouping exercises at night at a range of 1,000 yards. If necessary, add some low level illumination to the target to help with target contrast problems.

There are some examples of dialogue that you have seen in previous parts of this chapter. The observers are constantly challenged to come up with different engagement techniques and methods to “operate” their shooters. It is very important for the sniper teams to record the ENV and MET conditions as they relate to the night vision device. The percentage of illumination must be recorded. The location and power of illumination of the moon must be recorded as well as the moonshadow and its effect on the night vision system. As with the dedicated night vision system, total battery time must be recorded and under what conditions that clock time has been used is important. This determines the usable battery life of your system. Below is another example of a way to talk to the shooters. This is a bit more abbreviated, but gets the information across.

DIALOGUE BETWEEN THE OBSERVER AND SHOOTER WITH DEDICATED NIGHT VISION SYSTEMS ON THE WEAPONS

<u>OBSERVER</u>	<u>SHOOTERS</u>
“TARGET Bullseye Target #16”	“IDENTIFIED”
“ELEVATION, SET, Reverse Image Zero”	“ELEVATION, Index, Reverse Image Zero, Say point of aim.”
<i>This is a warning order for the shooter that he is going to use the Reverse Image Zero method of engagement.</i>	
“POINT OF AIM, Center X of Bullseye, 1000 meters”	“POINT OF AIM, Center X”
<i>The gun is zeroed at 1000 meters with this NVD. For a Reverse Image Zero, the point of aim and point of impact will be the same, therefore the center X hold</i>	
“CORRECTION FOR METEOROLOGICAL AND ENVIRONMENTAL FACTORS, Drop Point of Aim, 6 feet below center X on target”	“Corrections for MET and ENV, Point of Aim 6 feet below center X, Ready”
<i>It should be understood at this point that this gross of a hold under greatly reduces the success of an attack on a small target. On a large material target, the odds are still quite good</i>	<i>The shooter is ready to receive a wind holdoff and shoot at this point.</i>
“STANDBY FOR WINDS”	
“HOLD” CENTER” Observer checks his shooter and watches for trace and impact. Switch back and forth on other shots watching the shooter actions and the flight of the bullet.	BANG, The shot goes off and the shooter executes follow through and re-acquires the target.

3. **DAY/NIGHT COMBINATION NIGHT VISION SIGHTS.** These sights, or more correctly, this sight—the AN/PVS-10—is intended to be the final solution for a shortage that has long been a problem for military snipers. The jury is still out on this system, but the quick word is that these systems are outstanding. There are some other optical systems that fall under the category of day/night combination systems. These are the night vision systems that attach to the objective or ocular lens of the day optic.

The advantage of these systems is that the elevation and windage adjustments remain the same as the optic they replace (AN/PVS-10) or the day scope is integrated into the system and the elevation and windage adjustments are the same (McMillan Vision Master, U.S. Optics SN-3NV). Both of these systems attach their night vision tube to the ocular lens end of the day scope.

The obvious advantage of these systems is that you can treat elevation and windage settings the same because of the design of the optic. During this multiple-gun night shoot, observers are encouraged to further enhance their fire control procedures. Some ideas are:

- Have the guns index an elevation setting other than the one for the range you are at and have them execute a holdover or holdunder on the target.
- Give the windage corrections in mil holdoffs instead of MOA corrections.
- Target all guns onto a single bull's-eye target for a composite group, then fire all guns with a 5 shot volley group. This will leave between 10 and 15 impacts (depending on the number of guns online).
- Have the shooters index their elevation settings to zero and practice their indexing procedures at night when they can't see their elevation and windage knobs. This is an important exercise for the shooters to get used to their systems when they can't physically see them.
- As always, practice the dreaded remove and re-install of the sight system to determine its zero repeatability.
- Single target designation procedures using an IR laser or a high power IR flashlight system.

The 1,000 meter night vision known distance shoot is intended to prepare the shooting teams for unknown distance night shooting. On the known distance range the goal is the same as it is for the daytime

DIALOGUE BETWEEN THE OBSERVER AND SHOOTER WITH A PIGGYBACK NIGHT VISION SYSTEM ON THE WEAPON

<u>OBSERVER</u>	<u>SHOOTERS</u>
" TARGET Bullseye Target #16"	" IDENTIFIED "
" ELEVATION, INDEX, Index 36.75 Minutes "	" ELEVATION, Index, 36.75 Minutes "
" POINT OF AIM, Center X of Bullseye, 1000 meters "	" POINT OF AIM, Center X "
" CORRECTION FOR METEOROLOGICAL AND ENVIRONMENTAL FACTORS, Drop Point of Aim, 3.5 MILS below center X on target "	" Down 3.5 MILS "
<i>This MIL Holdunder method is much more accurate than the feet and inches holdunder that is necessary with dedicated night vision systems.</i>	<i>The shooter is ready to receive a wind holdoff and shoot at this point.</i>
" SPIN DRIFT, Left one-half minute of angle "	" SPIN DRIFT, Left one half minute, Ready "
" STANDBY FOR WINDS "	
" LEFT, 1 MIL " Observer checks his shooter and watches for trace and impact. Switch back and forth on other shots watching the shooter actions and the flight of the bullet.	BANG, The shot goes off and the shooter executes follow through and re-acquires the target.

KD shoot. That is to determine the capabilities of the guns and observer at long range under the conditions that exist. Because it is a known distance, you can determine the MOA capability of the HTI team with their guns and optics. It is stressed that trainers and operators play with different techniques. These methods that are discussed here are the minimums that are needed to introduce an operator to the Hard-Target Interdiction concept and the methods to train a shooter and observer into the world of extreme-range shooting. Training must be incremental and approached slowly and methodically. All information gained during these shoots must be recorded. Videotaping is advised for the same reasons that sports organizations videotape. It is much easier to identify errors, freeze the frame, and discuss solutions while that image is in front of the entire team. Use video and still imagery heavily in the training process. This leaves only one live fire training event to be discussed, other than full mission profiles.



The HTI observer uses a theodolite spotting system. He is well behind the guns.

NVD SHOOT 3 – UNKNOWN DISTANCE SCENARIO

The unknown distance scenario actually encompasses a few different range scenarios under this blanket title. All of the mechanics of the different scenarios remain the same. The major difference is in the engagement methods or more accurately the methods “of target attack.” The range at which these shots will be taken is usually going to be less than 1,500 meters. This is because of the limitations of the night vision systems. Granted the targets are of a larger nature, but you still have to have enough target resolution to get good sight picture. This is something that is usually ignored or maybe not quite given enough thought when shooting night vision optics. In the past, shooting NVDs was a compromise and most operators had little faith in their long range capability.

One of the major reason for shooting unknown distance shoots (this means unknown distance to the teams, not the instructors) under different ranges and different conditions is to determine their real-world best capability range. In all honesty, at night under 75 percent of conditions that exist at any one spot on the earth, your maximum night engagement range is going to be 1,300-1,400 meters. This is based on a few years of experience under all major environmental conditions including: desert, jungle, plains, grasslands, mountains, and over water. Working the known distance scenarios that are in this chapter will establish clean procedures and some good capability outlines for a hard-target team.

Through all of these range scenarios, the observers and shooters have been fine-tuning their dialogue and should be settling into a dialogue that is easily understood—at least to that team of operators—and brief. In the section on daylight unknown distance shoots we talked about range-finding operations. Details on these procedures are in Chapter 7. The focus of this section is based on different engagement procedures and the specific dialogue used in these procedures to engage targets of unknown distance at night. Some of this will cross over into application of fire procedures and you will see it again—if something doesn’t appear very clear here, it is covered in detail in Chapter 9.

Deliberate Target Attack

The deliberate target attack is a scenario that most snipers are familiar with. Basically, this involves a sniper element moving withing shooting range of a target that is known to them and has already been

pinpointed in its location. It also describes a target that has stopped and set up operations at a location where the sniper element will have time to do a detailed attack on that target. Setting up a hard-target team for an attack in the deliberate mode takes some time. While a team affords a little more security and freedom of movement because of their long standoff range, there are more things to be done other than sneaking one rifle and one observer into a final firing position (FFP). Dialogue as follows:

<u>OBSERVER</u>	<u>SHOOTER</u>
<i>"TARGETS", Gun 1, Scud Missile, Far Left, Gun 2, Scud Missile, Far Right, Standby"</i>	<i>"GUN 1, Identified"</i> <i>"GUN2, Identified"</i>
<i>"ELEVATION DATA, Gun 1, Index 36.75, Gun 2, Index 34.50"</i>	<i>"GUN 1, ELEVATION, Index 36.75"</i> <i>"GUN 2, ELEVATION, Index 34.50"</i>
<i>"ELEVATION CORRECTIONS, Drop 6.50 Minutes of angle"</i>	<i>GUN1, Correction, Drop 6.50 Minutes"</i> <i>GUN2, Correction, Drop 6.50 Minutes"</i>
<i>"BOTH GUNS, Say current elevation setting"</i>	<i>"GUN 1, Current Elevation 30.25 Minutes"</i> <i>"GUN 2, Current Elevation 28.00 Minutes"</i>
<i>"BOTH GUNS, Left 5.00 minutes, Standby"</i>	<i>"GUN 1, Left 5 minutes, Ready"</i> <i>"GUN 2, Left 5 minutes, Ready"</i> <i>Shooters are on target with elevation indexed and windage at 5.00 MOA for both spin drift and wind correction.</i>
<i>"BATTERY FIRE, BATTERY FIRE, Hold Center, READY, READY, READY, FIRE!"</i>	<i>BANG, The shot goes off and the shooter executes follow through and re-acquires the target.</i>

Snapshot Attack

A snapshot attack occurs when a hard-target team is moving into their position and a series of events occur that require them to engage targets as directed by the observer. This is the reason that the shooters try to get as much data on their guns as possible while they are in the objective rally point before they move into the FFP. When possible the observer can move forward and simply determine the range to the target, slant angle, and dominant wind conditions. He then returns to the ORP (objective rally point) and calculates his data. The shooters put this data on the guns and move into their FFP. During a snapshot engagement, the observer senses the need for an immediate attack on the target. If this target is a missile, they may need to attack because suddenly the missile is erected and this meets one of their pre-established criteria for a snapshot engagement. At this point, the shooters will have solid range data and an elevation setting that is precise for the range and MET conditions as they exist. The only real difference in the state of the guns between a snapshot attack and a deliberate attack is that the shooters will drop and shoot their pre-designated targets without further instructions from the observer. Dialogue as follows:

OBSERVER

In this scenario the observer has issued his preliminary elevation settings to the shooters in the ORP and they are moving into the FFP. As the target site comes into view, the OB sees that missiles are in launch configuration.

"SNAPSHOT, SHAPSHOT, Both Guns on Target, Immediate Suppression, State Ready"

SNAPSHOT, SHAPSHOT, is the warning for both guns to immediately acquire their targets; the guns may have to move a bit to do this. It may take a few seconds. The observer is waiting for a "gun on target" and "Ready" from the shooters.

"WINDS, Right 6 Minutes, Battery Fire, Standby"

The observer gives a wind call and a fire control command of "Battery Fire" to tell the shooters that he wants simultaneous fire on each target by each shooter on the observer's command. This cuts down exposure time by controlling each step of the engagement process.

"Battery Fire, Two shots each Target, Ready, Ready, Fire"

"Targets Engaged, return to ORP, Guns out first, I'll bring up the rear"

SHOOTERS

The shooters have indexed their data on the guns with NO DOMINANT WIND settings. They are moving to their individual locations in the FFP.

"GUN 1, SNAPSHOT, SNAPSHOT, gun on target, Ready"

"GUN 2, SNAPSHOT, SNAPSHOT, gun on target, Ready"

On hearing the warning "SNAPSHOT" both guns immediately acquire their targets, with initial elevation settings already in place and are waiting wind calls.

"GUN 1, Winds, Right 6 Minutes, Ready"

"GUN 2, Winds, Right 6 Minutes, Ready"

The shooters receive the wind call and tell the observer that they understand the Battery Fire command by saying "Ready".

BANG, Shots are fired, two on each target and the shooters are awaiting further instructions from the observer.

Shooters pick up and lead out returning to the ORP and departure from the target area.

Point Blank Zero And/Or Reverse Image Zero Attack

These two modes of attack are used when the hard-target team is in movement to an ORP (but not at the ORP) or when patrolling into their target area. It is used for engaging targets of opportunity where the threat of detection of the team is imminent, or the target is of high threat or value where an attack is mandated. These procedures would be nominated and approved in the pre-mission planning process. Details on these two methods are covered in Chapter 9. There is a specific sight setting on the gun that zeros that gun to a specific range. The size of the target is an important part of this process. An 11-meter missile target requires a zero of 1,100 meters on the gun. With that zero and the shooter aiming center mass of the missile target he will place an uncorrected shot somewhere on that 11-meter high missile to a range of 1,253 meters. I said uncorrected. This means that the data on the gun is for standard atmospheric conditions. The shot may impact high or low. The gunners will have to place a rough holdover or holdunder based on their quick assessment of the conditions (MET and ENV) at the time of the shot. This method is intended to get shots downrange no later than 1 minute after a target of opportunity is identified. We will examine a tactical scenario to explain how this process may be used.

A 4-man Hard-Target Interdiction team has successfully infiltrated an operational area where there suspected a mobile high altitude air defense missile launcher. The success of a pre-emptive air strike hinges on the successful removal of this target. The target cannot be fixed by satellite or human resources and its possible close proximity to other objects makes a blanket air strike or artillery raid impossible. The mission of the hard-target team is to fix and eliminate the mobile missile threat. In mission planning, the operators determined that their maximum engagement range can be only 1,200 meters. This is based on the terrain in

the area and some very limited line of sight areas. The height of the vehicle with missile laying down is 3.8 meters. The height of the missile when erected is 10.5 meters.

These two dimensions lay out the effective engagement ranges for using a Reverse Image Zero attack method, should the team encounter the target for a very limited time. The team examines their trajectory tables and determine that if they find a missile in the down mode on the vehicle, they should put a setting of 30.50 minutes for 900 meters (based on the maximum ordinate of the shot). For a missile standing up, they would put 67.50 minutes for a range of 1,400 meters on their guns. They have two rifles and decide to put one on 30.50 minutes for the movement and one at 67.50 minutes. This gives the team a gun ready to quick engage a target that is laying down to a range of 900 meters. If the missile is standing up the other gun is ready to go for a range of 1,400 meters. The team leader decides that if there is time, the non-ready gun can be re-indexed to the new elevation setting and join in on the fun. These methods are covered more in detail in Chapter 9.

The team is on the ground and is patrolling to several surveillance sites that they identified earlier. Their patrol routes take them close to roads and trails and also to places where they can overlook large amounts of the open patches of terrain that these systems may use to launch from. They know that normally these missiles would be in the travel mode but they must be ready for a missile in the launch mode. Since they may not know the enemy's intentions, they were given authority to engage without further permission should they find a missile in the upright mode. As they crest a rise in a hill, they hear diesel engines running and spot a site with a mobile launcher and a couple of support vehicles. The observer is evaluating the situation and suddenly the missile launcher rises to a vertical launch mode. The team leader instantly commands his shooters to acquire the target with their guns. Remember, this dialogue is only a guide and represents how it has been done in the past. The principle is that as long as the information is covered and is brief it's OK to use. Instructors will determine the acceptability of the dialogue. Dialogue as follows:

TEAM LEADER/OBSERVER

"TARGET, TARGET, Missile erect, immediate suppression, Say when ready"

While the shooters are getting into a position and on target, the observer sets up a scope, even if it's only the scope on his small gun. He also determines the wind data.

While the guns are working their targets, the observer should determine the true range to the target and correct for MET and ENV conditions. If necessary, he then can update his guns and give them new point targets.

"GUN 1, Shoot Reverse Image Zero, 2 shots each missile, winds left 3 MILS"

"GUN 2, Index 67.50 minutes. Shoot Reverse Image Zero, 2 shots each missile, winds left 3 MILS"

"BOTH GUNS, Target engine compartment, missile vehicle, INDEX 49.25 Minutes elevation, 2-shots, then target support vehicle, 2 shots, standby for winds"

"Winds, left 2 MILS"

As quickly as possible the team packs up their gear and moves out.

SHOOTERS

"TARGET, Missile erect, Standby"

When the shooters get this alert they move quickly to a shooting position, close to the observer, pick up the target and await instructions from the team leader.

"GUN 1, On target, Long Range Reverse Image Zero set, Ready"

"GUN 2, On target, Short Range Reverse Image Zero, set, Ready"

BANG, shots go off.

"GUN 1, rounds complete, standing by"

"GUN 2, rounds complete, standing by"

"GUN 1, Target engine compartment, missile vehicle, Index 49.25 minutes, Ready"

"GUN 2, Target engine compartment, missile vehicle, Index 49.25 minutes, Ready"

BANG, shots go off.

Teams are encourage to practice all three engagement techniques during day and night missions. The above scenarios seem to be tuned and developed for daytime shooting. That is because most snipers are used to daytime shooting situations. The night time allows for some very special engagements that are not necessarily possible during daylight hours. Operators that have suppressors for their systems are going to have a huge advantage. The suppressors cut down a great deal on muzzle flash and noise, of course. The above three attack scenarios apply to all weather conditions. They are mentioned here in the NVD section because this is the culmination of the shooting portion of the training for the HTI operator. All of these scenarios are intended to bring the shooter and observer up together through all of the possible range scenario combinations.

DETERMINING TEAM HIT PROBABILITY

It has been my experience that shooters of all sorts constantly need reminding that their rifles DO NOT shoot to a point. I have seen snipers look in bewilderment when a shot that they place at 300 meters impacts 2 inches to the right of the point of aim. A sniper system is a compromise between a benchrest rifle and a practical field rifle. With that compromise and some of the conditions that snipers operate in dictate that a .5-MOA rifle suddenly becomes a 2-MOA system when the shooter is attached and MET and ENV conditions are a little severe. Add to that the condition of some of the ammunition as it is used in battlefield conditions. As a matter of practicality teams should calculate their best expected shot group size on targets when they are shooting. This should be done on known distance targets as well as known distance targets.

It is important to determine a team's best hit capability at different ranges. Determining hit probability is an analytical process that requires a relatively large number of shots to be fired at a specific range. In this chapter, we have used three different range bands for engagements in the field and on the range. These three different ranges are supersonic flight range, transonic flight range, and subsonic flight range.

Hit probability can be explained this way: When a number of shots are fired from a rifle under the same MET and ENV conditions, it will be found that the shots have not fallen on the same spot but are grouped around a point on the target. Generally, this is due to deviations in the muzzle velocity at the gun and the initial yaw and pitch of the bullet as it leaves the barrel. This scattering of shots due to these unavoidable conditions is known as DISPERSION. Because of this dispersion, at long ranges (1,500 meters+) unless the target is large, a number of shots will miss even when all operator and calculator inputs are correct. Because of this uncertainty, it is a good idea to devise a method for determining this hit probability under given conditions and an expected MOA capability of the snipers and their weapons.

In the above analysis a sniper team with 2 rifles fired 20 shots at a target 1,000 meters away. In the above example using a 2-MOA precision standard this team is only 65 percent capable of hitting that target with 20 shots fired. The total group's overall MOA size is an average of 2.50 MOA. The average human being is 22 inches across the shoulders. Using that width as a standard and ignoring vertical deflection because a human is taller than 22 inches from neck to his crotch, this team has a 90 percent chance of hitting a human target at 1,000 meters with 20 shots.

However, considering that most hard targets are larger than 2 MOA, their percentages increase. Using a 3 MOA standard (34.14 inches) the team's percentage of hit goes up to 100 percent at 1,000 meters. Using this analysis technique a team can determine its good mid-range supersonic hit probability. The more shots that are fired, the more accurate the figures become. Teams can be dynamic about this method by shooting this procedure at night with night vision systems to determine their night time hit probability under the same conditions. The team can determine each individual's hit probability with any sniper weapons system using this same method.

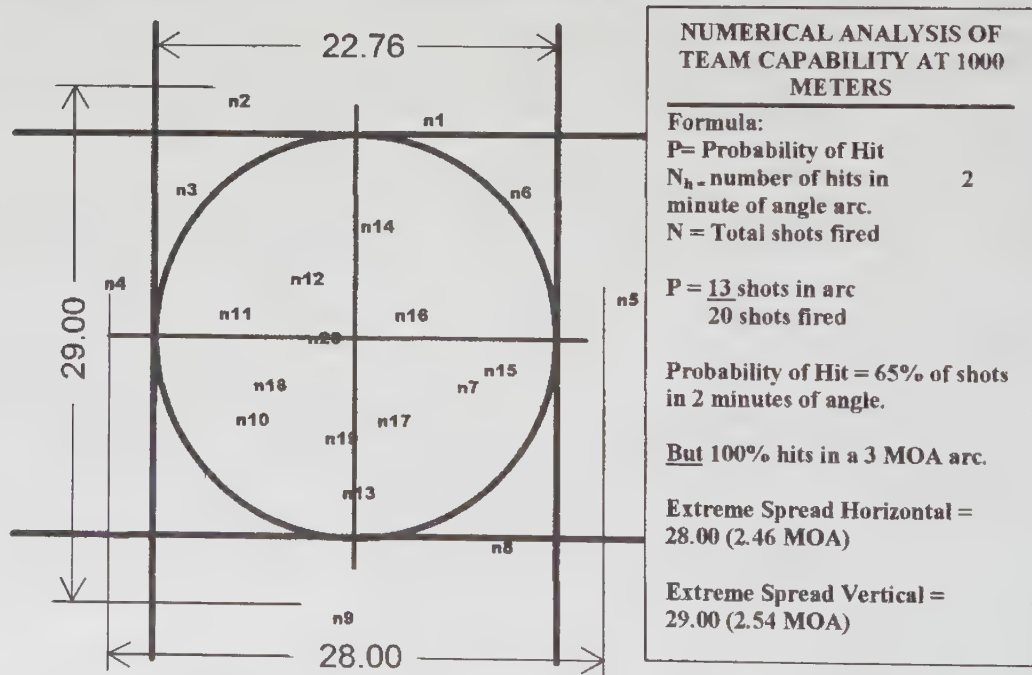
The shots in this case were fired at a range of 1,400 meters because under standard atmospheric conditions this round begins transonic flight at 1,400 meters + or - a few meters. This is the maximum range at which the 2 MOA standard is enforced on a sniper team. This is also the range at which the bullet under standard

conditions will remain stable before it begins its transonic disturbance as it slows down to subsonic flight. Though the HTI mission doesn't include human target interdiction, that possibility is always there and using the human target as a unit of measure, you can more easily appreciate the difficulty in extreme range sniping against personnel targets.

Operators should remember that when establishing their probability of hit, they should do everything possible to keep the conditions standard throughout the test. Ammunition should be stabilized at a certain temperature and that should be recorded. The team should keep a record of this shoot on one of the target sheets that are provided in Appendix A. These records should be kept by the sniper team leader or whoever maintains that record for the unit. They are an excellent mission planning tool. Also, when confronting personnel who are questioning their ability or why they can't engage from a farther range, the snipers can produce their real-world hit probability based on actual shots fired. This is a break from the norm as the claims made by shooters and leaders alike are usually blown out of proportion. As an example, I ran into a shooter at the SHOT Show in Atlanta 1999 who said that he could hit a human target at 3,800 yards with a .50-caliber rifle. Hmmm. Now let's take a look at a little further range, bordering on the absurd.

This analysis for the 1,700 meter shoot is a little different than for the other two ranges. In this case the bullet is definitely subsonic and subsequently the standard of accuracy changes from 2 to 3 MOA with 4 MOA being more reasonable. With all of the talk about shooting people at these extreme ranges, I thought I would throw the size of a human being based on a width across the shoulders of 22 inches. That circle is pretty small in comparison to the dispersion of shots on this target. That's not to say that it can't be done. It's just beyond the normal capability of a military grade .50-caliber rifle with military ammunition. Recently, however, a gun called the Windrunner set a new 1,000-yard record that was 1/2 MOA. Projecting this to 1,700 meters gives the shooter about a 75 percent chance of a first round hit on a human target. More about that later. There are rifles out there capable of operating at this range, but they're not .50-caliber guns.

1000 METER / 2 MOA TARGET



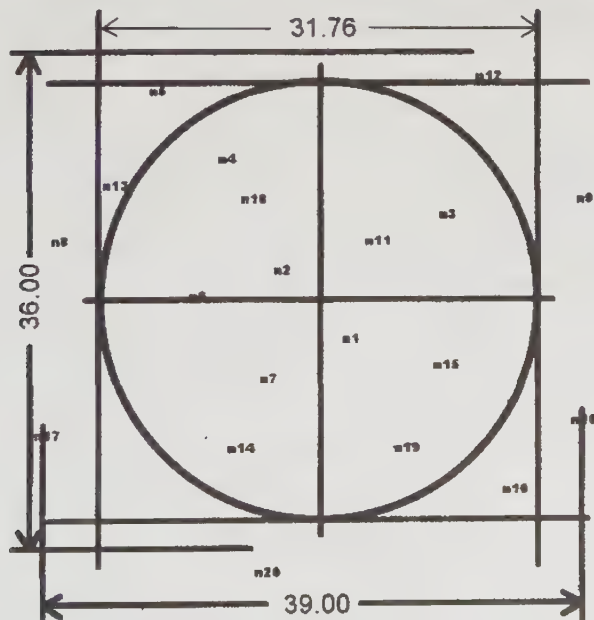
20 Shots fired at 1000 meters from a 2 gun HTI team.

CHAPTER SUMMARY

In this chapter I attempted to expose you to some problems and highlights of training special operators in the craft of Hard-Target Interdiction. In the beginning, some of the class dynamics that has been experienced were presented. These were the first building blocks that led to the development of most of the material that is included in this book. Clearly there will be some argument from the shooting community out there. That is OK, argument is encouraged, but try it before you condemn it. If I have stepped on any toes with any of this material, know that it was not intended. Some shooters may have seemed slighted by comments that high master shooters couldn't make the big guns work. That's not an opinion or anything but the facts as I have seen them. Of course there are some high masters as well as non-shooters that can make these guns shoot without any specialized training. This doesn't lump those levels of shooters into any group or class of shooters. It's just the way it is.

Shooters and observers received some special instruction in this chapter that will be expanded on as the book proceeds. It is especially expanded in Chapter 9, "Application of Fire," and Chapter 10, "Field Skills for Hard-Target Interdiction Sniper Teams." This chapter has given the building blocks to understanding the material in Chapter 9 and the execution of those advanced in Chapter 10. Lots of material in this chapter was repeated in different formats. This helps in the retention of the material. There are lots of checklists and formats for blank forms that will help trainers and operators keep track of mountains of data that will help them perform this difficult and meticulous mission. I have tried to explain some of the fundamental problems that occur when shooters begin shooting heavy-class guns. The effects of highly efficient, high volume muzzle brakes and zeros that go through changes were presented and some solutions were discussed. Trainers remember that any problem must be analyzed and picked to pieces. It can never be written off with a shrug of the shoulders. There are always answers.

1400 METER / 2 MOA TARGET



NUMERICAL ANALYSIS OF TEAM CAPABILITY AT 1400 METERS

FORMULA:

$$P = \frac{11 \text{ shots in 2 MOA arc}}{20 \text{ shots fired downrange}}$$

Probability of Hit = 55% of shots in 2 minutes of angle.

But 100% hits in a 3 MOA arc.

Human target is 1.38 MOA wide at 1400 meters.

Width of a SCUD missile is 3.71 Minutes of angle at 1400 meters.

This team's group at 1400 meters = 2.36 minutes of angle

20 Shots fired at 1400 meters from a 2 gun HTI team

NUMERICAL ANALYSIS OF TEAM CAPABILITY AT 1700 METERS

FORMULA:

$P = \frac{15 \text{ shots in 3 MOA Arc}}{30 \text{ shots fired by team.}}$

Probability of Hit = 50% of shots into a 3 MOA arc.

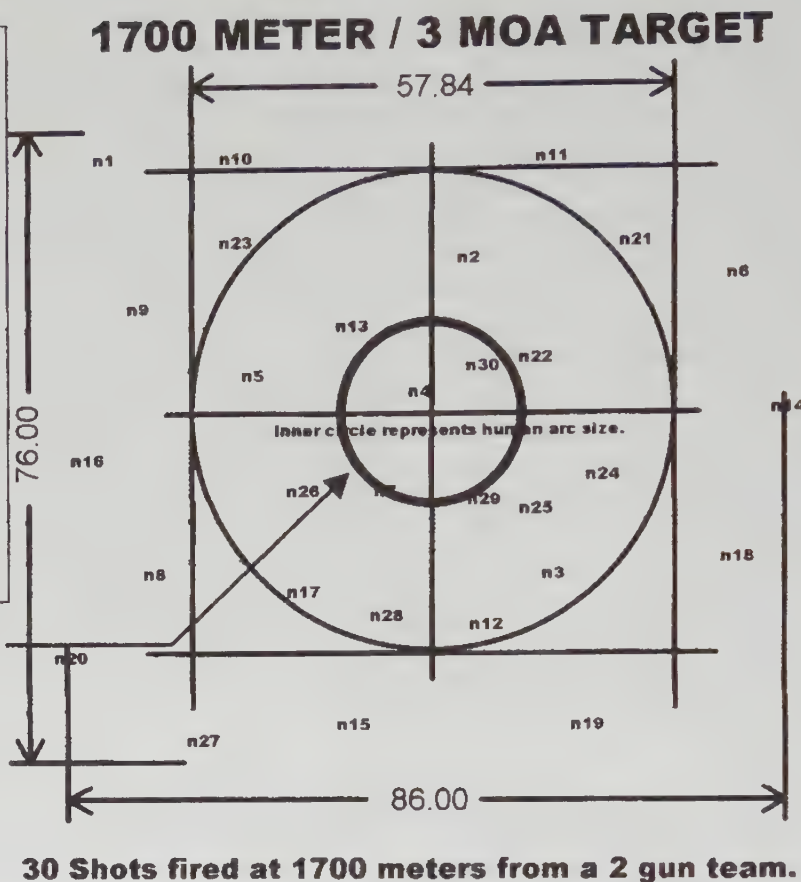
Probability of Hit = 95.2% of shots into a 4 MOA arc.

3 MOA = 57.84"

4 MOA = 77.12"

Human being is 1.14 MOA at 1700 meters.

The human being at this range is only 1.14 MOA angle wide. Note that only 4 out of 30 shots fired at this range impact in this arc. This is a very difficult engagement for the best of shooters. Better ammunition would help this data.



The known distance range scenarios are intended to break shooters and observers into the procedures that will allow them to work unknown distance shooting scenarios. Each scenario adds a level of difficulty and technical challenge that is unique to this sniper mission. The unknown distance scenarios add even more challenge to the observer. Teams will evolve through a series of difficulties and find faster and better ways to do things. Dynamic techniques for engaging multiple targets and targets of considerable depth must be practiced and bugs worked out between shooters that have different optics and different weapons. There still is no standard heavy-class rifle within the special operations forces. The reason that this book was written was to try to address all the different systems that are out there and tailor the special training to each of those units and systems.

Something called supersonic burnout range was for the first time introduced to sniper operations. This subject is not used in high-angle trajectory indirect fire or in anything else in the ballistics business. It is only used in Hard-Target Interdiction and extreme range anti-personnel shooting. This is the part of long range shooting that kind of blows some holes in some of the claims about shooting personnel targets to 2,000 yards or more. I'm not saying it hasn't been done. I know that it has. But when I have talked to a couple of the people who did it, they admit a good bit of luck. Part of this is based on the range finding technique the used and when asked about MET and ENV conditions, they don't know what I'm talking about. About this 2,000-meter anti-personnel stuff. Know how accurate your range has to be to hit a 6-foot-tall man anywhere on the

body? You only have a bracket error of 24 meters. Split that in half and you can only be short by less than 12 meters or long by no more than 12 meters or the shot lands at his feet, or goes over his head. More on this later also.

A little bit of trickery was introduced in the section on unknown distance shooting at night. A procedure called Reverse Image Zero and Point Blank Zero was mentioned. This is covered more in detail in Chapter 9. They are some very advanced techniques that blow big holes in determining range by mil relation. Sorry, guys, I'm not a believer in mil relation, unless the target is big and not moving.

Finally, hit probability was addressed. This is a common practice in older field artillery, naval gunnery, and aerial bombing. For conventional sniping missions it has no practical value. It does, however, for the very refined operational sniper, tell him about his real capability under the conditions in which he patterns his rifle and himself. It is an excellent mission-planning tool, and when properly recorded may save an operator's life from an overzealous officer that thinks a particular mission can be done (and by the way, they're never on the ground on one of these). I hope that this chapter has been helpful in painting the picture on Hard-Target Interdiction operations. This subject is continued in more depth in the next chapters of this book.

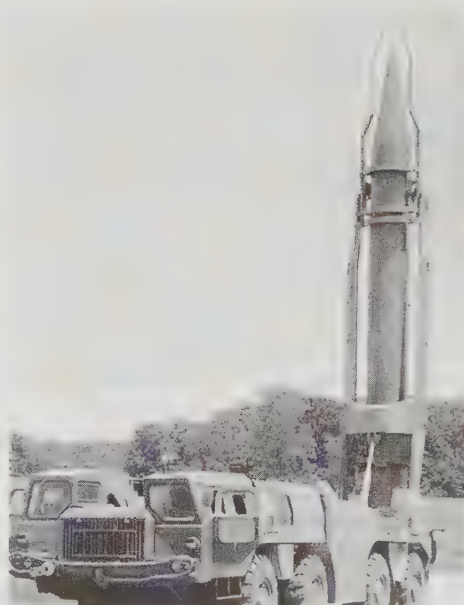
CHAPTER 9

Application of Fire

I would like to quote something from TC 31-20-4. That is the manual produced by the SOTIC staff at Fort Bragg, NC. Some have said that this course is the same as any course offered by Fort Benning or the U.S.M.C. at Quantico, VA. SOTIC is different in a few ways and the same in others. One of the areas that SOTIC is different is their training in a subject I call "Application of Fire." I quote the following:

"Following the Austrian-Prussian War of 1866, the Prussian Army began a systematic study of the effectiveness and control of small arms fire. The result of this study, conducted over a 6 year period, was the introduction of the science of musketry, a misnomer as all major armies were by then equipped with rifles. Musketry is the science of small arms fire under field conditions, as opposed to range conditions. It is concerned entirely with firing at unknown distances; thus, the importance of the study of musketry to the sniper. The material presented is merely an overview of the fundamentals of musketry. At the peak of the study of musketry as a martial science, musketry schools often extended their courses to six weeks duration. Only the introduction of machine guns and automatic small arms precipitated the doctrine of its study. Various aspects of musketry were retained as separate subject, such as judging distances and issuing fire control orders. This study ties together the scattered remnants of the study of musketry as it pertains to sniping."¹

The material that is going to be covered in this chapter concerns only unknown distance methods and theory. It is recommended that the reader review Chapter 5, "Sight Adjustment and Zero of the Heavy Rifle"



The threat SCUD.

if need be when talking about information on sights in this chapter. Be concerned about the section on the values of the adjustments of the different sights and the explanation of units of measure in Chapter 5. The material in this chapter is often referred to as the "Black Magic" of unknown distance shooting. True, there are some tricks in here, but many shooters commonly know a portion of this. There is one subject, though, that I think about 99 percent of the shooting community has never heard of. I have mentioned in other chapters that much more detail will be covered on a particular subject in Chapter 9, "Application of Fire." Well, here we are in Chapter 9, and here we go.

I am going to add a couple of tables here that will aid in reading this material. These tables are about the value of certain angular units of measure.

In Chapter 5 the different units of measure were explained. This quick reference table is a good aid when a shooter is determining things like group size, holdoff

conversions or when determining how high or low a shot will strike on a target. This is of great use in range determination. While a shooter is becoming accustomed to the use of MOA or mils in their dialogue process.

The second column shows the value of a MOA in inches. For 1/4 MOA divide by 4. 1/2 MOA is divided by 2 and so on.

The last column in the table shows the value of the 3/4 MOA diameter Mil Dot in the reticle pattern. This is the most common pattern in sniper optics. It can be helpful in determining a quick range to a target when the size of a particular object is known.

Example: A human head is approximately 10 inches in diameter. A shooter places one of his Mil Dots over the head and it just covers that object.

Referring to the table above for an object of about 10-inch size, you trace to the left and see a range reference of 1,200 meters. This method is helpful when you want to get a fast range to target for a Reverse Image Zero shot or maybe a PBZ shot on a material target.

The next table lists values for partial and full mils. It works for many things. As with the MOA table above, this next table is useful for teaching operators the value of those quarter and half mils when a bullet misses a target, or when calculating their leads for moving targets. When a shot misses 6 inches to the left of the target, a quick look at this table can tell him the correction he needs to give the shooter.

MINUTES OF ANGLE VALUE TABLE

RANGE (M)	VALUE OF 1 MOA	VALUE OF MIL DOT
100 METERS	1.13 inches	.850 inches
200	2.27	1.70
300	3.4	2.55
400	4.5	3.40
500	5.67	4.25
600	6.86	5.00
700	7.9	5.90
800	9.1	6.80
900	10.23	7.60
1000	11.38	8.50
1100	12.51	9.40
1200	13.65	10.2
1300	14.78	11.0
1400	15.88	11.9
1500	17.05	12.8
1600	18.24	13.5
1700	19.28	14.4
1800	20.48	15.3
1900	21.61	16.1
2000	22.76	17.0
2100	23.89	17.8
2200	25.03	18.7
2300	26.16	19.5
2400	27.26	20.4
2500	28.43	21.3
2600	29.62	22.0
2700	30.66	22.9
2800	31.86	23.8
2900	32.99	24.6
3000 METERS	34.14 inches	25.5 inches

VALUE OF FRACTIONAL AND FULL MILS (INCHES)

RANGE	.25 Mils	.50 Mils	.75 Mils	1.00 Mils
100 Meters	.984	1.97	2.95	3.94
200	1.96	3.94	5.90	7.88
300	2.95	5.91	8.85	11.82
400	3.94	7.88	11.80	15.76
500	4.92	9.85	14.75	19.70
600	5.9	11.8	17.7	23.6
700	6.87	13.7	20.6	27.5
800	7.88	15.7	23.6	31.49
900	8.85	17.7	26.5	35.43
1000	9.84	19.7	29.5	39.37
1100	10.83	21.6	32.5	43.3
1200	11.8	23.6	35.4	47.2
1300	12.8	25.6	38.4	51.2
1400	13.7	27.5	41.3	55.1
1500	14.8	29.5	44.3	59.0
1600	15.8	31.5	47.3	63.0
1700	16.7	33.4	50.1	66.9
1800	17.7	35.4	53.1	70.9
1900	18.7	37.4	56.1	74.8
2000	19.7	39.3	59.0	78.7
2100	20.6	41.3	62.0	82.7
2200	21.6	43.3	64.9	86.6
2300	22.6	45.2	67.8	90.5
2400	23.6	47.2	70.8	94.5
2500	24.6	49.2	73.8	98.4

TABLE CAN BE USED TO DETERMINE THE ERROR IN INCHES AT RANGE FOR WINDS AND ELEVATION CORRECTIONS.

FURTHER USE IN DETERMINING THE SIZE OF OBJECTS WHEN THE RANGE IS KNOWN OR THE RANGE WHEN A CERTAIN SIZE OBJECT IS KNOWN.

For example, a team is practicing engaging moving targets. The range is 300 meters and the shooter has just fired a round that was 9 inches behind the target. Looking across the range band for 300 meters, the observer finds 8.85 inches, which is the value of $\frac{3}{4}$ mil. He then adds $\frac{3}{4}$ mil to the lead that he gave the shooter. This should correct the lead provided the shooter broke his shot clean and the wind correction was correctly applied to the lead correction.

Another application of this table is for quick range determinations. A sniper team is observing their target and they have a diagram that shows the size of different objects on that target in inches (for example a truck window that is 40 inches across). One of the shooters notes that it is 1 mil across the width of that 40-inch window. Looking under the column for the value of 1 mil, we find a reading of 39.37 inches that corresponds to a range of 1,000 meters. This method hasn't been covered because it is used to establish a quick range for a snapshot. It is not precise range determination and it is not a visual estimation using the eye and the rules of target, terrain, and light conditions. This method is easily practiced by placing cardboard boxes of different sizes downrange. The teams have the sizes of these boxes for reference. The object is to see how

quickly and accurately the teams can determine the range to the target using the above table and their mil reticle system. When a team is proficient, this is quite accurate.

EXTERIOR BALLISTICS AND TRAJECTORY ANALYSIS

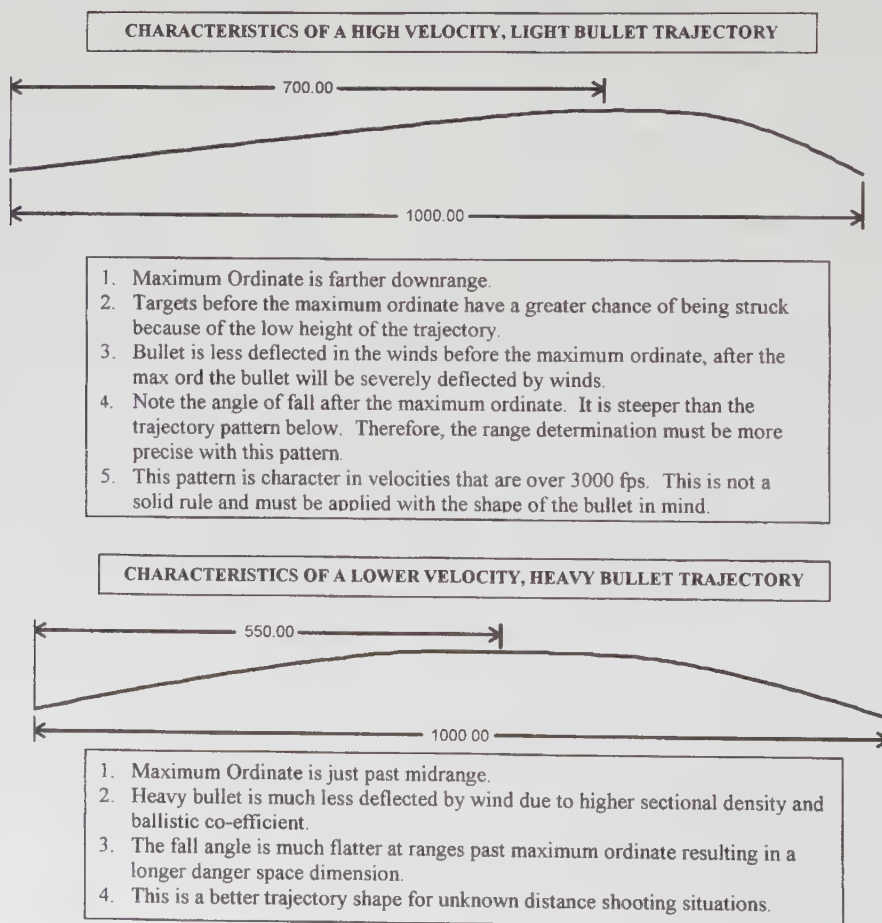
You were introduced to the subject of exterior ballistics in Chapter 6. In this section, we are going to go a little deeper into to subject of exterior ballistics and trajectory analysis as the two are forever tied together.

Does a bullet rise in flight? The short answer is no. If a barrel were placed horizontal to the earth with a zero degree angle of elevation, as soon as the bullet left the confines of the barrel and traveled downrange (x-axis), it would start dropping toward the earth (y-axis). This motion is caused solely by gravity. Air resistance on the front of that bullet retards its forward velocity. The third component is the winds (z-axis). For the bullet to strike a target that is anywhere past the muzzle (within reason), the barrel must be elevated to a calculated setting above the line of sight. This is referred to as the angle of departure. We are used to it being

referred to as a come-up or elevation setting. On scopes with BDC knobs, numbers that represent the range in hundreds of meters (most common) depict these departure angles. On telescopic sights with 1/4 MOA or other incremental click adjustments, we must refer to a table of elevation settings. These settings must be in standard atmospheric conditions or they won't mean anything at long ranges when the MET conditions are different from standard.

Two very important properties of the trajectory are air resistance and gravity.

- **Air Resistance.** The shape of the trajectory is based on air resistance. Gravity has nothing to do with the shape. There is a relationship between initial velocity and air resistance. The faster the initial velocity out of the gun, the greater the air resistance. This also means that the bullet will slow down faster than a heavier bullet of the same caliber. Consequentially, a heavier bullet with a slower initial velocity loses velocity slower and carries its energy farther. This relationship is important in that lightweight, high velocity bullets will have a flatter trajectory for a certain distance than the heavier bullet. Heavyweight, lower velocity bullets of the same caliber will have a more parabolic shape to their trajectory and have a longer flight time. These trajectories have a shallower fall angle past the mid range and are better for long range shooting. They also have higher ballistic co-efficients (in the same caliber and shape as the light bullets) and resist being pushed around by the winds more. As we will learn later, these two trajectory shapes also greatly affect the danger space dimensions. Heavier bullets with a parabolic shape to their trajectory have a greater danger space dimension because of a lesser fall angle to their trajectory. Examine the diagram below:

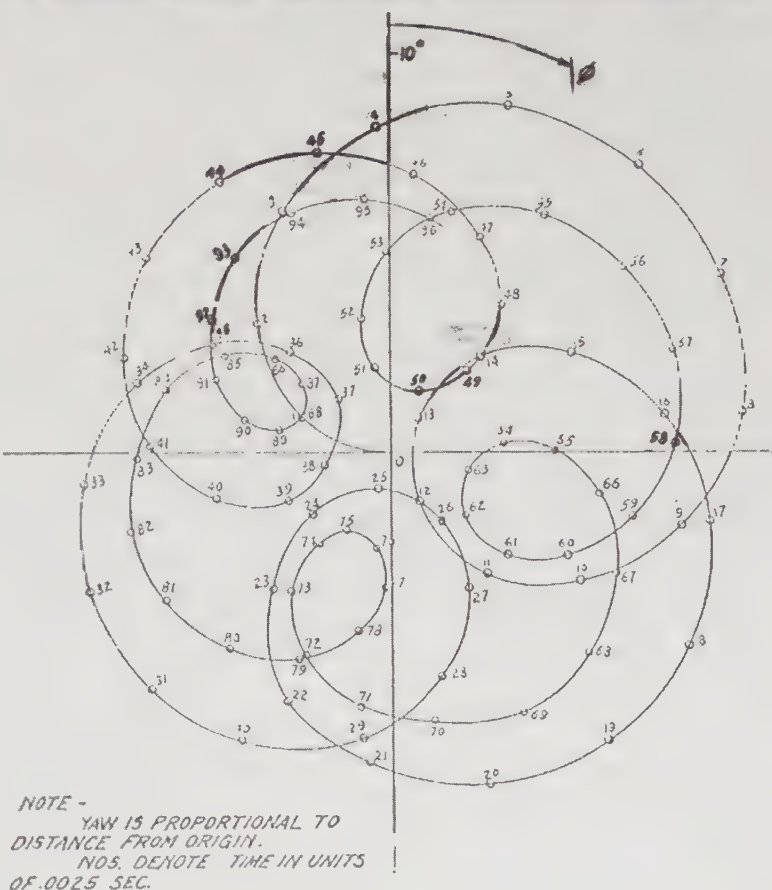
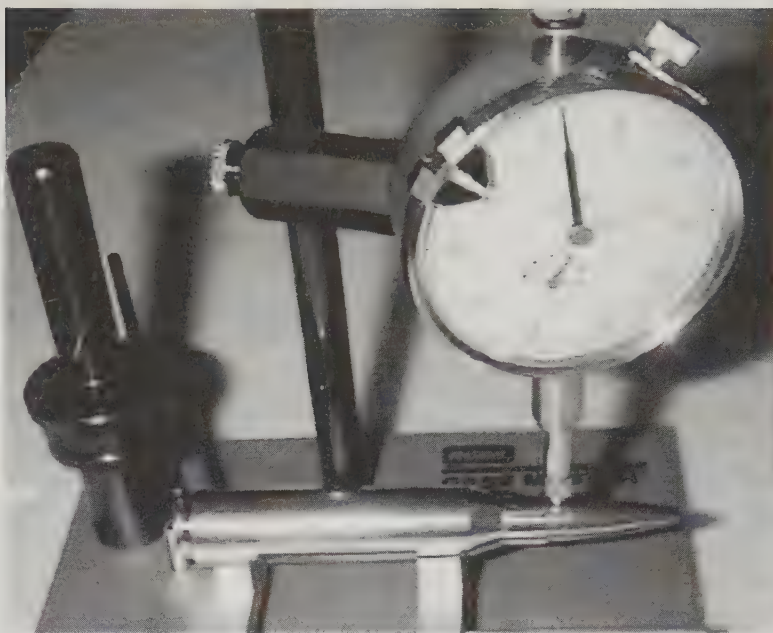


This information is important to a long-range shooter for a couple of reasons. Many competitors use a couple of different loads for different situations. A military shooter may not have this option, but some may have. For the civilian shooter or someone with the authority to use their own loads, there is a good reason for crafting loads with trajectories that meet the above criteria.

- **Gravity.** Gravity influences the bullet in flight equally all the way to the target. Gravity does not affect the shape of the trajectory, however. It is a physical force that must be corrected for as well as air resistance when determining an angle of departure. Once factored into the formula, it does not change with MET conditions. There is a time when you must correct for gravity effects. That is when you are shooting on an angle uphill or downhill. That is covered in detail later in this chapter.

When a number of rounds are fired from a rifle with a given angle of departure, not all of the rounds will impact on the same point on the target downrange. Remember when I said that the standard for a shooter, his rifle, and his issued ammunition was 2 MOA? Included in this figure are the factors that affect the flight of a bullet; variations that affect where the bullets will impact occur when a bullet is fired, even when the angle of departure doesn't change. Some of these variations are shooter-induced and some are not.

One variation that is not shooter-induced is changes in muzzle velocity due to the differences of powder ignition in the cartridge case. Benchrest and other reloaders strive to control this variation by using match grade primers, weighing cartridge cases, and being as precise as



Depiction of bullet yaw caused by severe bullet runout.

possible when measuring out the powder load into the case. For example, five cartridges in .300 Winchester Magnum, each case having exactly 81.5 Grains of H-1,000 powder under a 185 grain Lapua Match bullet still resulted in a deviation in the muzzle velocity of 22 fps. As a general rule, a change in the muzzle velocity of 50 fps will cause the round to strike 1 MOA high or low depending on the gain or loss in the velocity.

Another small variation in the muzzle velocity comes from differences in the ammunition temperature. Ammunition that is setting in a cold box out in 30-degree air will have a lower velocity than a round that has been warming up in the chamber of a hot gun. Chapter 6 contained the instructions on how to correct for this problem.

One aspect of precision reloading deals with loading the bullet very close to the rifling of the bore. There are several theories on why this makes a difference. Vibrations in the barrel are a major part of rifle accuracy. The stronger the frequency of vibration, the more the group at the target is affected. When the bullet has to make a large leap to the rifling, it is possible for it to be slightly misaligned in the bore. This is due to bullet runout, or the bullet not being perfectly straight in the rifle case. When the bullet impacts with the bore and it is out of alignment, two things happen. First, the bullet slams into the bore, slightly misaligned, and the bullet gets slightly deformed as it passes through the bore of the gun. Second, this more than normal impact sets up a strong vibration in the gun. The result is that the very end of the rifle barrel is just slightly out of position in relation to shots before and shots after. Consider what happens when 20 rounds of ammunition are fired and the standard runout is .005 inch or more. At SOTIC we once measured the runout of 10 rounds of M118 Special Ball ammunition (military sniper standard). The average was .008 inch. That's pretty bad runout.

Variations can also occur that are shooter influenced. Any misalignment in the sights and their placement on the target certainly will affect the size of the shot group. One very well known shooting coach, Lt. Commander Art Seivers, said that shooting is only two things. Actually, this is his personal definition: "Shooting is aligning the sights with the eye and moving the trigger so as not to disturb this alignment."² He said moving the trigger is the biggest problem shooters have. In a demonstration, he had one of our snipers aim a Daisy air pistol at a blank sheet on a wall 10 meters away. The shooter did not have his finger on the trigger. The guns were revolvers. When the shooter was confident that his sights were aligned, he was to nod his head. When this happened, Art reached up and pulled the trigger for him while facing away. He did this 5 times and the group was just under an inch wide at 10 meters. Art never looked at the sights and the shooter didn't pull the trigger. That made a believer out of me, two other fully qualified Level I snipers, a master class NRA shooter and, needless to say, 20 sniper students.

The effect of yaw on a bullet in flight causes some special problems also. Yaw affects the accuracy of the bullet because the bullet is oscillating around the point of aim. Sometimes this settles down as the bullet goes downrange, other times, it opens the shot group. Although some would dispute this, some gun systems will group worse at shorter range and as the bullet settles down the group tightens up (MOA measurement) as the bullet travels downrange. A few years ago when M-33 Ball was such terrible ammunition, this was much the case. The jackets were not concentric and the core of the bullet was not well centered in the jacket. What happens is that when the bullet leaves the barrel, this out-of-balance situation ends up with a bullet that flies like the image on the previous page. Good quality bullets have a much smaller oscillation. Bad bullets that have non-centered cores have a larger oscillation. Typically though, some of this oscillation settles down and the groups will stay within a certain MOA size and not get any larger. Other rounds, however, do not settle down and the group gets larger as the bullet goes downrange.

The second effect of this oscillation is that more of the area of the bullet that is not the tip is exposed to the air in front of the bullet. This increases the drag on the bullet and the overall effect is to lower the ballistic co-efficient. This changes the shape of the trajectory. Rounds fall short at times. This can result in some of those unknown little "flyers" that occur when shooting groups, especially at extended ranges. "The greater pressure on the side of the projectile more directly exposed to the airstream will tend to push it at right angles to the direction of motion. In addition, the oblique presentation will considerably augment the total component of force along the direction of motion, that is, yaw increases head resistance, or drag."³

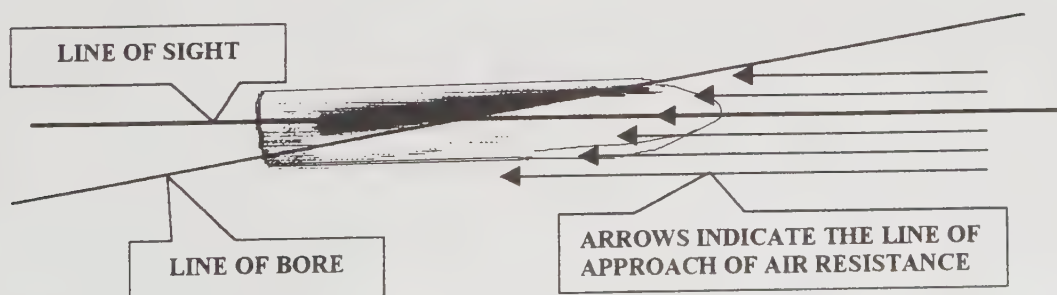
Air resistance is the most important consideration in the shape of the trajectory. If gravity alone was the major factor that determined the shape of a trajectory, bullet trajectories would be an even curve. The fall angle for a shot would be the same as the angle of departure. That's not the case. For example, a Mark 211, Mod-0 shot for 1,600 meters has a departure angle of 1 degree 29 feet 15 seconds (89.25 MOA). The fall angle for the same shot is 2 degrees 59 feet 35 seconds (or 179.50 MOA). The fall angle is almost twice the departure angle. This fall angle is a major factor in determining the danger space of a shot and directly affects the degree of precision in determining the range to a target.

Spin drift is also a result of air resistance to a bullet in flight. Air resistance combined with the rifling in the barrel and the high RPM of a bullet flying downrange all combine to push a bullet in the direction of the twist of the gun (right-hand twist barrels result in bullet drift to the right). Spin drift was for a long time ignored at the U.S. sniper schools. Some instructors knew of its existence but they deemed it to be of such a small effect that it could be ignored. When we had the students shoot their M-24s at 1,000 yards in no wind conditions, the bullet still impacted about 1 MOA to the right. This is under *no wind conditions*. A call to the U.S.M.C. Scout-Sniper Instructor school at Quantico, VA, in 1989 presented the following question. "When you guys shoot at 1,000 yards under no wind conditions, are you getting a right-hand drift?" The answer was yes, about 10 inches or so (1 MOA). This confirmed our suspicions. It took a bit of research before a formula was discovered that allowed us to calculate this drift. In the Naval Gunnery text, they address the problem but write it off with high angle trajectories. "This applies to direct fire. When the angle of departure exceeds 70 degrees, as it sometimes does in mortar fire, the drift is reversed in direction."⁴

What causes this no-wind drift? As the bullet leaves the gun, the line of approach of the oncoming air ceases to impact *directly* against the tip of the bullet. This is because of the curve of the trajectory. In other words, the barrel is elevated to hit the desired point on the target. The bullet leaves the barrel nose high on that angle of departure. The air it encounters is on the same angle to the bullet as the bullet is to the line of sight. Refer to the image below.

This tends to raise the nose of the bullet. That action combined with the high spinning rate of the bullet causes the nose to drift in the direction of spin, much like a top does. Then the nose of the bullet moves in a downward direction. All of this in combination with the angular motion of the tangent caused by the trajectory keeps the nose of the bullet on the side of the plane of fire towards which it was first deflected (to the right). This motion continues downrange. The Mark 211, Mod-0 bullet at 1,600 meters is deflected 26.57 inches, under standard atmospheric conditions (1.50 MOA). With bullets fired out of a right hand twisted rifle, the bullet's nose will always remain to the right side of the plane of fire.

We have examined two properties of a trajectory—air resistance and gravity. The effects and causes of spin drift of a bullet were also covered in painful detail. All of this is done so that the sniper can better understand what his bullet is doing in flight. The higher the velocity of the bullet, the greater the air resistance. The shape of the trajectory is also less parabolic in nature. All bullets drift to the right in a right hand twisted barrel. The corrections for this effect in a .50 caliber rifle with most of the ammunition starts at 1,000 meters. At ranges less than 1,000 meters, the deviation from drift is not enough to be concerned with.



The trajectory is further affected by some other factors. These conditions affect the drag on the bullet and therefore impact on the length of the trajectory, but not its shape. The method for determining the value of and correcting for these factors was covered in Chapter 6. However, here is a little more of a description of these affects on trajectory and on drag on the bullet.

- Temperature.** Air temperature affects the trajectory in two different ways. One effect is on external ballistics and one is on internal ballistics. Concerning external ballistics, the higher the air temperature the less dense it is. The air molecules are spaced further apart and the drag on the bullet is less. Consequentially, the colder the air, the more drag on the bullet. That is why you divide the correction factors against the elevation settings when the temperature is greater than 59 degrees F. and multiply when it is colder than 50 degree F. Air temperature also affects the muzzle velocity of the rifle. When ammunition is sitting out in ambient air, eventually it becomes the same temperature as the air around it. The standard temperature for ammunition is 70 degrees F. It is at this temperature that muzzle velocities are standardized. When the temperature is lower than 70 degrees, the powder burns slower. This results in a lower muzzle velocity. Above 70 degrees, the velocity is faster. When using the Mark 211, Mod-0 round there is a 1 MOA change in elevation when the temperature drops to about 40 degrees F (30 degrees below standard). However, that same 1 MOA change occurs when the ammo temperature is 85 degrees F. (15 degrees above standard). Note that 1 MOA change doesn't occur over an even curve. Another phenomenon is that the higher the initial muzzle velocity, the more variation in ammo temperature happens at different temperatures. This error in muzzle velocity is one of the most common problems when operators re-check their gun zeros and aren't aware of ammo burn rates. It affects the trajectory at all ranges.

AMMUNITION BURN RATE CONVERSION CHART

STANDARD AMMUNITION TEMPERATURE OF 70 DEGREES

AMMO TEMP	CONVERT FACTOR	V= 2840 Mark 211	V=2910 M33, M8	V=2950 M20	V=3950 SLAP
30 Deg.	-.0241	-68 fps - 1 MOA	-70 fps	-71 fps	-95 fps
70 Deg.	.0000	No Change	No Change	No Change	No Change
90 Deg.	+.0228	+65 fps + 1 MOA	+66 fps	+67 fps	+90 fps

The Temperature Effects Analysis table shows the general effect of the air temperature on elevation settings. Note how the changes in the elevation settings are non-existent at the shorter ranges (to 500m). At 1,000 meters, the effects are starting to show up, but a degree doesn't make much difference with Mark 211, Mod-0 ammunition. At the nominal operational range of 1,500 meters, a 10 degree air temperature change equals 1 MOA at the target. This is 17.05 inches and is not much on a hard target of some size. On a human target, 17 inches high or low is a near miss or a miss altogether. There has been mention of sniping human targets at 2,000 meters. Note the MOA value change for only 10 degrees at 2,000 meters. Three MOA at 2,000 meters is 68.28 inches. That is extreme and cannot be ignored. Do the math. Two-thousand-meter anti-personnel sniping sounds easy? That's not even taking into effect a bullet doing a transition from supersonic flight to subsonic flight. Don't forget that these temperatures affect the burn rate. This table only addresses the ambient air temperature. The error is compounded if the ammo burn rate is ignored. If it is 90 degrees outside and the ammo is the same temperature, the error at 1,500 meters becomes a +6.00 MOA error, or a high strike of 8.5 feet above the shooter's point of aim.

• **Barometric Pressure /
Altitude Above Sea Level.**

Barometric pressure and altitude are the same effect as far as external ballistics is concerned. If you can determine the pressure and can correct for it, you are correcting for altitude. The standard barometric pressure at sea level for shooting (as set by Aberdeen Proving Grounds) is 29.53 In. Hg. The problem is that barometric pressure goes up and down all the time. It can easily vary by an inch throughout the day, in some places. The standard deviation in most places I have been is about a half an inch. There are a set of standard barometric pressures and temperatures for altitudes above sea level. These standards can be used when the actual BPs and air temps are not known. An important point to know is that while there are standards, those conditions can easily be quite different. For example, Denver is 5,280 feet above sea level. However, if you have been there, you know that it can get up to 100 degrees F.

quite easily. The standard temperature is only 37.6 degrees F. The bottom of the following table shows the gain in supersonic range as a result of a lower barometric pressure based on altitudes above sea level. What this means is the team has a more effective maximum engagement range. More standoff equals more security. That doesn't mean that the range determination will be harder, though. Because the elevation setting is much lower, the trajectory is much lower. Once you complete page 3 of the calcforn, you will know the supersonic burnout of that round when it is fired. That burnout range is bounced off the danger space table to determine the level of accuracy required to hit the target (even though at that point, you will have determined the range to the target). Though the target may be 2,000 meters away, the elevation setting may be for an equivalent 1,300 meters because of MET and ENV conditions. This means that the maximum ordinate and fall angle will be for 1,300 meters. The danger space will be 70 meters for a human 2 meters tall. That's not too difficult to obtain with a theodolite. The bottom line is that as the barometric pressure drops, the bullet encounters less resistance and therefore less drag. Less elevation is needed to

TEMPERATURE EFFECTS ANALYSIS

THIS IS AN ANALYSIS OF TEMPERATURE EFFECTS ON THE LISTED TYPES OF .50 CAL. AMMUNITION. ALL CHARTS IN THIS DATA BOOK ARE SET AT A STANDARD OF 59 DEG. F.

M-33 BALL / M-8 ARMOR PIERCING INCENDIARY

<u>RANGE</u>	<u>48</u>	<u>58</u>	<u>68</u>	<u>78</u>	<u>88 DEG.</u>	<u>CHANGE</u>
100 M	3.7 MOA	3.7	3.7	3.7	3.7	NONE
500 M	14.3	14.2	14.2	14.1	14.0	+ - 0.1 MOA
1000 M	36.6	36.2	35.9	35.6	35.2	+ - .35 MOA
1500 M	75.9	74.4	73.3	72.0	70.7	+ - 1.3 MOA
2000 M	136.9	133.4	130.8	127.9	125.0	+ - 3.0 MOA
2500 M	216.9	210.8	206.2	201.1	196.0	+ - 5.3 MOA

MARK 211, MOD-0 RAUFOSS SPECIAL PURPOSE

<u>RANGE</u>	<u>48</u>	<u>58</u>	<u>68</u>	<u>78</u>	<u>88 DEG.</u>	<u>CHANGE</u>
100 M	3.8 MOA	3.8	3.8	3.8	3.8	NONE
500 M	15.0	14.9	14.9	14.8	14.8	+ - 0.1 MOA
1000 M	38.8	38.4	38.0	37.6	37.2	+ - 0.4 MOA
1500 M	80.6	79.1	77.7	76.3	75.0	+ - 1.4 MOA
2000 M	144.0	140.8	137.7	134.7	131.7	+ - 3.1 MOA
2500 M	226.8	221.1	215.6	210.3	205.1	+ - 5.4 MOA

M-903 SLAP SPECIAL PURPOSE

<u>RANGE</u>	<u>48</u>	<u>58</u>	<u>68</u>	<u>78</u>	<u>88 DEG.</u>	<u>CHANGE</u>
100 M	2.6 MOA	2.6	2.6	2.6	2.6	NONE
500 M	7.1	7.1	7.1	7.0	7.0	+ - .06 MOA
1000 M	15.5	15.4	15.3	15.3	15.2	+ - .06 MOA
1500 M	26.3	26.1	25.9	25.7	25.5	+ - .20 MOA
2000 M	40.5	40.0	39.6	39.2	38.8	+ - .43 MOA
2500 M	59.6	58.6	57.8	56.9	56.0	+ - 1.0 MOA

FOR STUDY ONLY, DO NOT APPLY DATA AS CORRECTIONS

strike the target and the wind effect on that bullet is less. More on the wind effect later. When the BP is up, there is more resistance on the bullet and your supersonic range is shorter, unless temperature affects cancel this out.

- **Humidity.** Humidity is a subject that seems to be somewhat overrated. It is also confused with a couple of other MET effects. Basically, humidity as a factor to worry about and to correct for doesn't exist. Here are two examples the effect of humidity on a shot. There is an error in TC 31-20-4 (ID). On page 3-41 it is stated that "That is, when humidity goes up, impact goes down; when humidity goes down, impact goes up."⁵ The opposite is true. Sierra's Reloading Manual, 50th Anniversary Edition, a very respected source states, "The molecular weight of water is lower than the molecular weight of dry air (18 vs. 29), for any specified atmospheric temperature and pressure the density of humid air is lower than the density of dry air. Consequently, there would be more drag on a bullet in dry air than in humid air, provided temperature and barometric pressure remained the same in both cases."⁶ Note that in the below circumstances the elevation setting for both cartridges is lower when the humidity is at 100 percent, but not by enough to worry about.

.338 Lapua Magnum 300 gr. @2,850 fps / 0 percent humidity = 87.8 MOA @ 2,000 yards
 .338 Lapua Magnum 300 gr. @2,850 fps / 100 percent humidity = 86.8 MOA @ 2,000 yards
 Difference is less than 1 percent of the Elevation Setting for 2,000 yards

M118 Special Ball 7.62mm 173 gr. @ 2,600 fps / 0 percent humidity = 53.6 MOA @ 1,000 meters

STANDARD PRESSURES AND TEMPERATURES

ALTITUDES ABOVE SEA LEVEL

ALTITUDE	PRESSURE	TEMPERATURE
SEA LEVEL	29.53 In. Hg.	59.0
1000'	28.67	55.4
2000'	27.84	51.9
3000'	27.02	48.3
4000'	26.22	44.7
5000'	25.44	41.2
6000'	24.68	37.6
7000'	23.94	34.0
8000'	23.21	30.5
9000'	22.50	26.9
10000'	21.80	23.3
11000'	21.12	19.8
12000'	20.47	16.2
13000'	19.82	12.6
14000'	19.19	9.1
15000'	18.58	5.5 deg. F

GAINS IN SUPER-SONIC FLIGHT RANGE BASED ON ELEVATIONS ABOVE SEA LEVEL

R/1500 M TO TARGET	ELEV. GAINED	VELOCITY GAINED	ENERGY GAINED	SUPER-SONIC FLIGHT RANGE
2500' ASL	-6.60 MOA	+ 70 fps	+ 222 fp	1650 meters
5000' ASL	-12.00	+ 153 fps	+ 501 fp	1850 meters
7500' ASL	-16.50	+ 246 fps	+ 838 fp	2000 meters
10000' ASL	-20.30	+ 342 fps	+ 1212 fp	2200 meters
12500' ASL	-23.40	+ 440 fps	+ 1612 fp	2400 meters
R/2000 M TO TARGET	ELEV. GAINED	VELOCITY GAINED	ENERGY GAINED	SUPER-SONIC FLIGHT RANGE
2500' ASL	-12.60 MOA	+ 47 fps	+ 125 fp	1650 meters
5000' ASL	-24.10	+ 99 fps	+ 268 fp	1850 meters
7500' ASL	-34.20	+ 157 fps	+ 440 fp	2000 meters
10000' ASL	-43.10	+ 227 fps	+ 660 fp	2200 meters
12500' ASL	-50.50	+ 309 fps	+ 930 fp	2400 meters

M118 Special Ball 7.62mm 173 gr. @ 2,600 fps / 100 percent humidity = 53.4 MOA @ 1,000 meters
 Difference is less than 1 percent of the Elevation Setting for 1,000 meters

We have covered the factors that affect the shape of the trajectory, the effects of gravity (more on this later) and some of the deeper reasons behind the MET effects that we learned how to determine and correct for in Chapter 6. With a further understanding of trajectory, we are now going to move a little deeper into trajectory analysis by learning how to use some of these trajectory patterns to our advantage. There are some other factors that are independent of the trajectory, but are critical to the unknown distance shooter.

The term maximum ordinate refers to the maximum height the bullet will reach above the line of sight on its flight to the target. The term ordinate refers to the height of the bullet at any point along the trajectory on its flight to the target. That point may be at 300, 500, 700, or any other distance between the muzzle of the gun and the target. Ordinate tables are usually developed that show multiple heights of bullets at any point downrange. The analysis of these two figures lead us into some more of the “Black Magic” of long range unknown distance shooting. The methods used to engage targets without using range determination methods all use trajectory analysis and ordinate and maximum ordinate data. We are going to analyze the trajectories of a Mark 211, Mod-0 bullet in flight for three different zero ranges.

2500 METER ORDINATE TABLE (in feet) FOR MARK 211, MOD-0

Range	100	200	300	400	500	600	700	800	900	1000	1100	1200
ORD.	18.9	37.4	55.4	72.7	89.3	105.3	120.3	134.3	147.1	158.5	168.3	176.3

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500
182.2	185.7	186.6	184.7	179.8	171.4	159.4	143.7	123.9	99.9	85.3	38.2	0.0

Note that in the above table the maximum ordinate occurs at 1,500 meters downrange. This is well past the mid-range of 1,250 meters. This gives you an idea of the shape of this trajectory. It is not a good parabolic curve. It is more similar to the curve on the bottom of the two curves on page 282. The maximum ordinate is 186.6 feet above the line of sight.

1400 METER ORDINATE TABLE (in feet) FOR MARK 211, MOD-0

Range	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
ORD	6.2	11.9	17.1	21.6	25.1	28.2	30.1	30.9	30.4	28.3	24.5	18.7	10.7	0.0

In the 1,400-meter ordinate table, the maximum ordinate of 30.9 feet occurs at 800 meters downrange. In the case of the 2,500 meter ordinate, the maximum ordinate occurs at 60 percent of the range to the target. In the 1,400 meter table, the maximum ordinate occurs at 57 percent of the range to the target. This shows you that the further the range to the target, the further downrange the maximum ordinate will occur. In most cases though, in trajectories where the velocity is less than 3,000 fps, the maximum ordinate will occur at around 60 percent of the range to the target.

MORE ON DANGER SPACE, DANGER RANGE AND SWEEP SPACE

There is a distance in front of the muzzle in which the bullet does not rise higher than the object being fired at (or the critical component of any target). This distance is one part of danger space. The other part of

danger space occurs after the bullet has passed the maximum ordinate (in the falling branch of the trajectory) and is again below the height of the object being fired at and continues to the ground. That part of danger space that occurs within the falling branch is the horizontal dimension that is part of the firing tables that we use to determine our range determination accuracy requirement.

Let's take another look at the ordinate table for a 2,500-meter and 1,400 meter shot. Note the height of the ordinate at 100 meters (18.9 feet) and for the range of 2,400 meters (38.2 feet). There is quite a difference in the height of the bullet for these two ranges. The bullet is 49 percent higher at 100 meters from impact than it is 100 meters from the end of the gun. This is another indicator of the shape of the trajectory. It also indicates the steepness of the angle that the bullet is falling the final 100 meters to impact.

2500 METER ORDINATE TABLE (in feet) FOR MARK 211, MOD-0

Range	100	200	300	400	500	600	700	800	900	1000	1100	1200
ORD.	18.9	37.4	55.4	72.7	89.3	105.3	120.3	134.3	147.1	158.5	168.3	176.3

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500
182.2	185.7	186.6	184.7	179.8	171.4	159.4	143.7	123.9	99.9	85.3	38.2	0.0

1400 METER ORDINATE TABLE (in feet) FOR MARK 211, MOD-0

Range	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
ORD	6.2	11.9	17.1	21.6	25.1	28.2	30.1	30.9	30.4	28.3	24.5	18.7	10.7	0.0

At this point, it's time to review both the definition of danger space and the factors that affect the danger space dimension: Danger space is a horizontal measurement expressed in yards or meters. As the bullet goes past maximum ordinate and travels downward towards impact with the ground (ignoring the target), the danger space measurement begins at the point where the bullet is equal to the top (height) of the target and continues to when the bullet impacts the ground (again, ignoring the target).

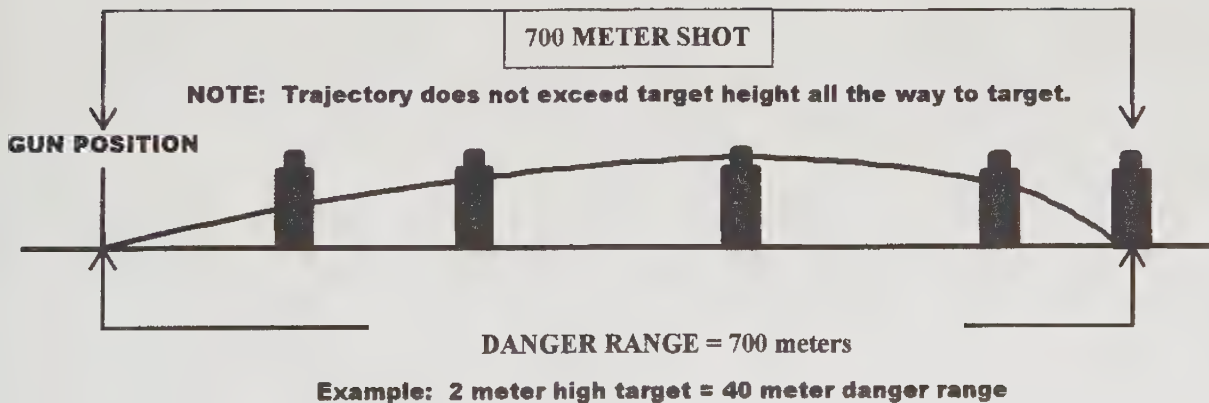
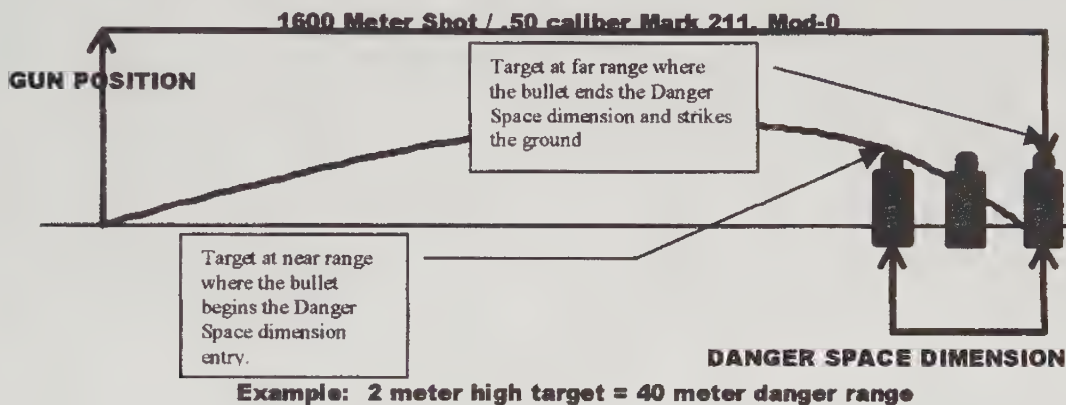
- **Height of the barrel off the ground.** (In the tables in this book, the barrel height is set at 6 inches off the ground. This matters in ranges only to about 700 yards. At the ranges used in HTI operations, this factor is irrelevant.
- **Height of the target.** This figure is used two ways. There is the overall height of the target. With missile targets this figure is OK, because a missile cannot sustain a hit anywhere on it without sustaining some kind of damage. On targets where there must be a specific point of attack, the size of this particular object becomes the height of the target. Whereas a 6-foot-tall (1.83 meter) man would appear to have a danger space dimension of 137 meters at a 1,000 meter shot with .50 caliber, Mark 211, Mod-0 ammunition, the 137 meter figure isn't accurate

The figures on the next page show the depiction of a 40-meter danger space that was extracted from the danger space table for Mark 211, Mod-0 ammunition for a 1,600-meter shot. The danger space dimension begins when the bullet is the same height of the target or the critical kill zone and continues to the ground. Usually center of mass is accepted as the point of aim for the target or the critical component for attack. In the 700-meter shot table (next page) there is also a section referred to as the danger range for a shot. The danger range as mentioned in Chapter 7 refers to a situation where the trajectory is such that the bullet

DANGER SPACE OF SELECTED TARGET SIZES (METERS) MK-211, MOD-0

RANGE	1M	2M	3M	4M	5M	6M	7M	8M	9M	10M	11M	12M	13M	14M	15M
500M	500														
600M	600														
700M	209	700													
800M	159	234	800												
900M	120	175	900												
1000M	96	137	219	1000											
1100M	76	108	168	233	1100										
1200M	68	96	149	206	1200										
1300M	50	70	108	147	188	231	275	1300							
1400M	41	58	88	120	152	186	221	257	294	1400					
1500M	34	48	73	98	125	152	180	208	237	267	298	1500			
1600M	29	40	61	83	105	127	150	174	197	222	247	272	298	324	1600

DANGER SPACE IN THIS ZONE IS REPRESENTED BY THE RANGE TO THE TARGET. MAXIMUM ORDINATE DOES NOT EXCEED THE HEIGHT OF THE TARGET. **THIS IS REFERRED TO AS THE DANGER RANGE.**



NEVER rises above the height of the target. This dimension is critical later when we discuss Reverse Image Zero and Point Blank Zero shooting methods. This depiction shows the effect of danger range and its trajectory curve.

The term swept space refers to a horizontal measure that changes with the lay of the terrain. This dimension does not affect the degree of accuracy required to determine the range to the target. It doesn't much matter whether the target is uphill or downhill as far as the degree of accuracy required when finding

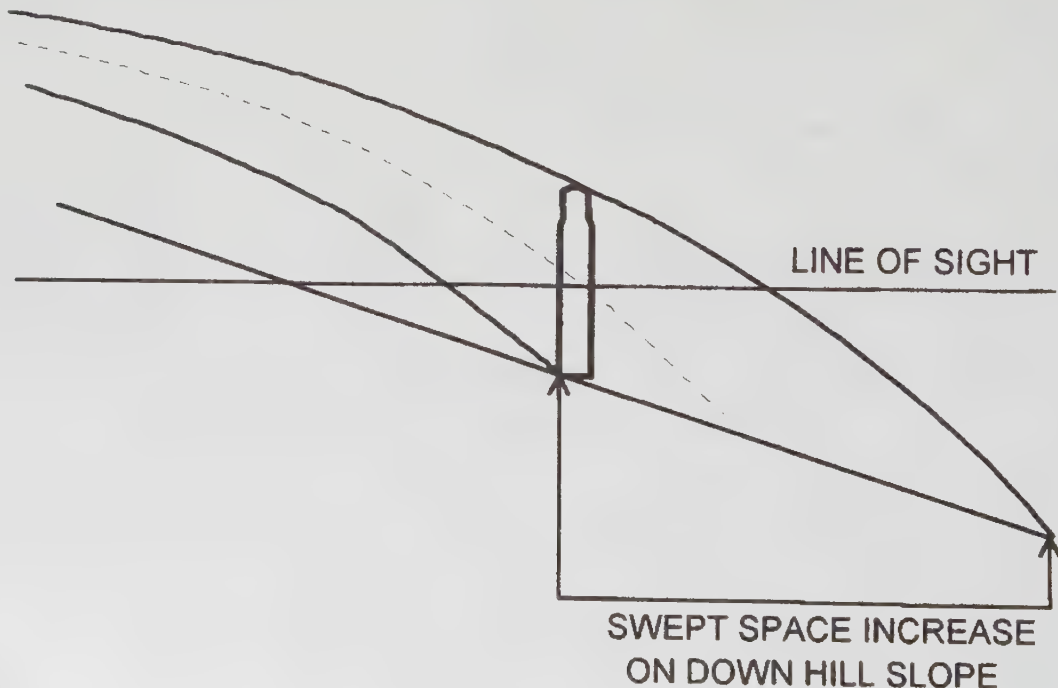
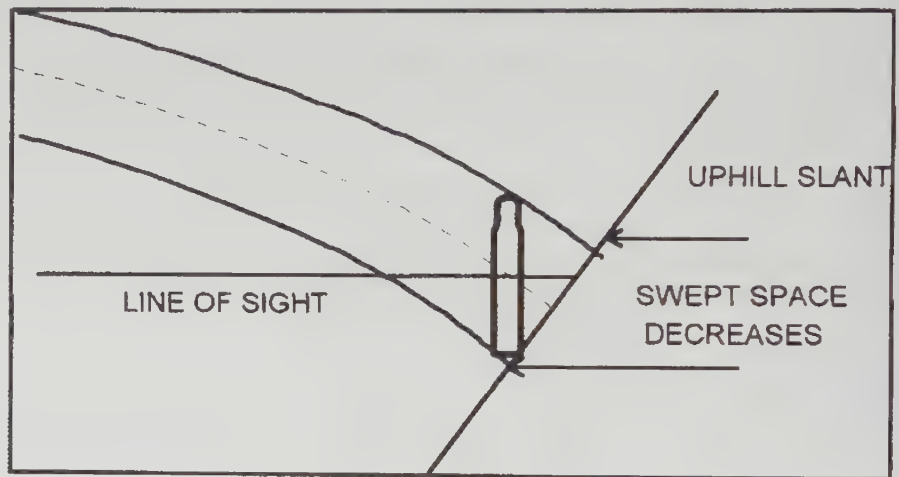
the range. Remember though, that uphill or downhill angle will make the target appear smaller to you and your optical systems. The only rangefinding equipment NOT affected by uphill or downhill angle is the laser range finder.

Here are two rules on swept space:

1. On ground that is rising in front of the shooter, the swept space dimension will decrease.
2. On ground that is falling away from the shooter or sloping downhill, the swept space dimension increases and may easily continue for hundreds of meters.

Consider the two rules above. In this depiction, the dotted line represents the trajectory for the point of aim on that target. The two dark lines represent the trajectories for points of aim at the top and at the bottom of the target. The swept space is the measurement on the ground that the group of shots would cover. The major effect and concern of this upward slanting ground is that the target is only a step or two away from leaving the cone of fire. During the time the shot is fired he can easily move uphill or downhill and the round will either pass over his head or under his feet.

In this depiction of a shot on a target that is standing on downward sloping ground, you can see that a target would have to move quite a distance before he would be out of the cone of fire. This is a great aid to unknown distance shooters and can be used to your advantage.



This rule does not apply when the shooter is located on higher ground looking down on a target that is standing on flat ground. The danger space figure is shorter because of the angle caused by the gun being higher than the target. Your range determination must be more precise. So when considering shooting at a target when you have some choice in the terrain around the target, the old rule of dominating the high ground is good. Try to set up so that the target is on a downhill slope from you or so that you are on higher ground. Remember the rules of swept space are written with the gun being at the same altitude as the target. That is, there is no slant angle involved here, only that the target is standing on ground that is sloping upward or sloping downward.

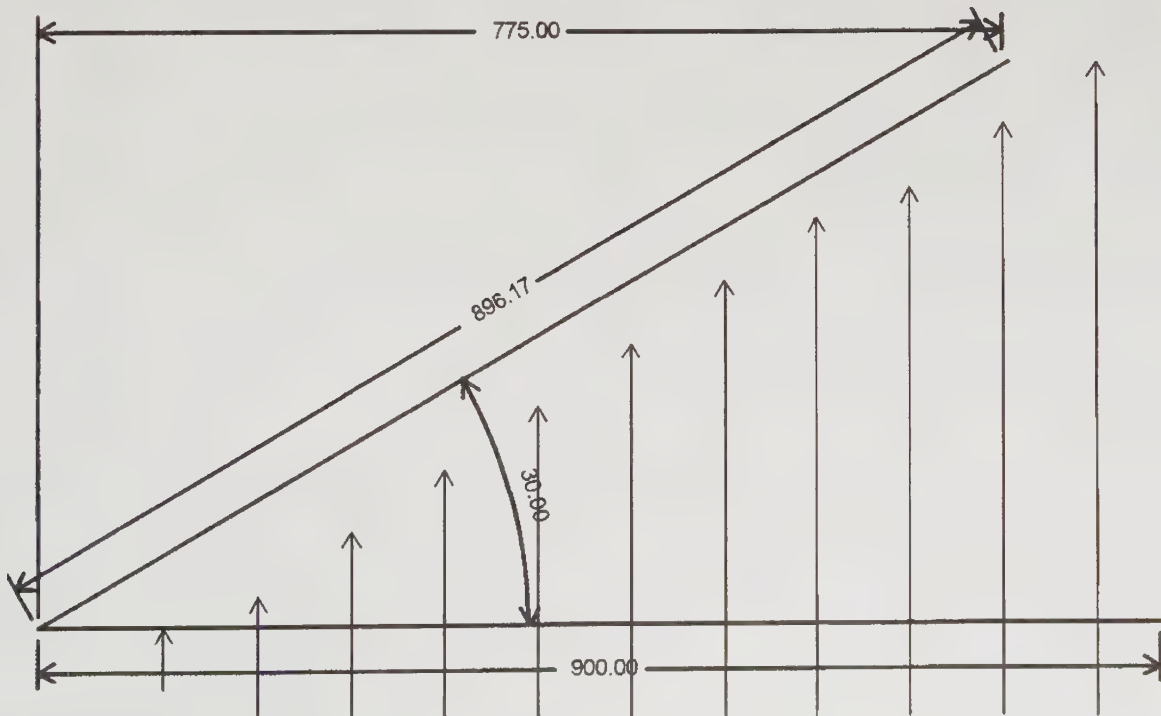
EFFECTS OF SHOOTING UPHILL OR DOWNHILL

The effects of shooting uphill or downhill have been long known. In Chapter 7, we discussed the causes of this phenomenon and we did the technical corrections for the slant angle. As stated in Chapter 6, the effects of gravity at the earth's surface are considered to be equal and perpendicular to the surface. We know that the earth is curved and that gravity emanates from the center in all directions roughly equally. At the surface however, because of the vast size of the planet and the relatively short distances we shoot, the gravity "waves" are 90 degrees to the surface of the earth. This is what causes the effect on a bullet that is fired uphill or downhill. You will always shoot high in either case. This drawing shows that when you shoot on an angle, you expose less of the trajectory to those perpendicular lines of gravitational flow. A reminder from Chapter 6, however. Remember that the slant range setting is your first setting on the gun. All of the MET and ENV conditions corrections are based on 900 meters in this example. The winds are also corrected for a range of 900 meters. Example:

Range to Target = 900 Meters

Angle of Line to Target = 30 degrees (COS) = .86603 Correction Factor

900 Meters (true range) X .86603 = 779.5 Meters Slant Range



SLANT ANGLE EFFECT

We discussed the effects on the apparent height of a target to the naked eye or through optics in Chapter 7. Any target that is standing on a slant angle up or down from the shooter will appear to be smaller than it really is. These effects are independent of the 3 conditions that affect visual range estimation. Remember to correct your Angle C readings for target height for the slant angle to the target. Failure to do this will cause you to come up with a range to target this is farther than reality. Whenever correcting ANYTHING for slant angle from the gun to the target, your solution should come up smaller. Because of the reduction in gravitational effect, your required elevation settings are going to decrease. Now the question is, can this help you? You bet it can. Shooting uphill or downhill will do a few things for you. When you correct the range for slant angle, your elevation setting before MET and ENV conditions will be smaller. This means that your supersonic flight range is going to be farther and your long range precision is higher. Remember, the closer to transonic flight your bullet is, the less accurate it becomes. This is also a general rule and some bullets are more susceptible to this effect than others are.

This slant angle effect ties in nicely with the effects of swept space. Remember that swept space increases on ground that is sloping away from the shooter. The target has to move farther in or out to get out of the cone of fire. Because the trajectories for a slant range shot is lower (lower maximum ordinate), the swept space is increased even more. You get the double effect of gain from sloping away ground (increased swept space) and a lower maximum ordinate (the danger space is increased).

BLACK MAGIC

The use of the term "Black Magic" may make a few shooters out there chuckle. I rather did also. Something that I have learned over the course of getting into the very fine art of extreme range shooting is that there were huge training gaps in the service

SLANT RANGE DETERMINATIONS

FORMULA FOR DETERMINING THE SLANT RANGE:

1. **Vertical Distance** $(\text{ATAN}(\text{COS}) \times \text{RANGE TO TARGET}) = \text{SLANT RANGE}$
Range to Target

2. Determine your range to target (Mil, Laser, Theodolite, GPS)
3. Determine your vertical distance above or below your target.
4. Divide the Vertical Distance (VD) by the Range to Target (HD).
5. Press the "ATAN" or "TAN-1" key on your calculator.
6. Press the "COS" key on your calculator.
7. Multiply the result of the above process against the Range to Target.
8. Result is the Slant Range.

SLOPE ANGLE IN DEGREES

Corr. Factor

5	.99619
10	.98481
15	.96593
20	.93969
25	.90631
30	.86603
35	.81915
40	.76604
45	.70711
50	.64279
55	.57358
60	.50000
65	.42262
70	.34202
75	.25882
80	.17365
85	.08716
90	.00000

FAST REFERENCE TABLE FOR USE WITH A PROTRACTOR STRING METHOD.
INTERPOLATE BETWEEN 5 DEGREE INCREMENTS.

Formula for correcting True Range by using COS of Slant Angle.

COS of Angle to Target X True Range = Slant Range
 $30^\circ (\text{COS } .86603) \times 1500 = 1299 \text{ Meters}$



This is a training site in Indonesia that we used to train members of the Indonesian Special Forces and their Presidential Security Detail on the effects of extreme slant angle shooting in an urban environment. We were able to cover all angles from 0 to 90 degrees from the gun to the target.

schools about the subject. The mil relation formula seemed to solve all of the problems. However, many missed shots occurred. Then there is the problem of correcting for MET and ENV conditions. These factors are addressed very lightly in all of the sources that are out there. Even with the advanced methods of range determination that are in this manual, there are still training gaps in engaging targets both soft and hard targets. What about those situations where you don't have the time to get a range to a target. Those times when you are being chased or have more targets than you really care for in a short period of time. How are you going to handle those targets? What about snap engagements that are talked about in Chapter 8? There is reference to Point Blank Zero and Reverse Image Zero engagements—what are these?

The term "Black Magic" is a term that we used at SOTIC, 1st SFGA to describe the next methods of engagement that use tricks of trajectory. Through the analysis of different trajectories, sizes of targets, uphill or downhill shooting angles, and final elevation settings after corrections for MET and ENV conditions are made, Black Magic is applied to engage certain classes of targets.

The first of these methods is using downhill and uphill shooting angles to our favor. In many instances, shooters and hunters didn't like uphill or downhill because they knew or suspected that the bullet would impact at a different point than expected. Many believed correctly the shot would go high under both circumstances. Some thought high when shooting downhill and low when shooting uphill. Others thought the opposite of that. However, now that we know the real effects of shooting on these angles and that the elevation settings are lower when shooting on the slant, can we use this to our advantage?

Whenever we can lower the number for our elevation setting, we are in a gain situation. The key is

determining how much gain we have and what use is it to us. As I said before, when you are correcting the true range to the slant range the numbers must get smaller. We are going to analyze a shooting situation where we are going to only consider the gain obtained by shooting on a slant angle. The MET and ENV conditions are going to be ignored except for slant angle. Since this manual is about .50-caliber rifles, we will use the Mark 211, Mod-0 round for this analysis:



Training slant angle shooting methods and some "Black Magic" to Indonesian security forces in January 1995.

A Hard-Target Interdiction team is departing a target after putting 6 rounds of tungsten steel through a surface to surface missile battery in an unnamed country. While they don't believe that they were compromised, they set up an ambush just below a ridgeline where their extraction landing zone is located. The team is nervous because the helicopter is still an hour away and there is a good road that runs from their target area through the valley below the extraction landing zone. They are also concerned because the team knows that if anyone on the target is smart enough to figure it out, they would be able to determine the rough direction of their shots. Quickly the team works out a security plan while two members determine the range into the valley. The team is equipped with .50-caliber rifles, a .338 Lapua Magnum rifle, and two M-4 carbines with 40mm grenade launchers attached.

They work out the range into the valley to the center of the target area to be 1,100 meters. They measure the angle into the valley and find the angle to be 35 degrees. With a look at their data tables, they determine their initial elevation setting to be 42.75 meters. They look at their "Secondary Functions" table and see the maximum ordinate to be 14 1/2 feet above line of sight. However, they're not done yet. They calculate their slant angle correction:

$$1,100 \times \cos 35 (.81915) = 901 \text{ Meters}$$

The elevation setting for 900 meters is 30.50 MOA. Again, they check their tables to get the maximum ordinate for the slant range of 900 meters. This is good news as the Maximum Ordinate for 900 meters is only 6.7 feet above line of sight. The snipers can put this information to good use. They know that the vehicle with a reaction force will stop right around the 1,100 meter mark. However, the effective range to the target is 900 meters because of the gravity factor. The team decides to get the ranges to two other points on the ground. This they can do with a map and that will be accurate enough. Armed with this information



Shooters calculated 1,100 meters true range, 901 meters slant range, with a 35-degree angle to the target.

they know that there is no need to range any of the targets out to the 1,100 meter mark. They decide that they are going to use two different engagement techniques. Initially, they will engage with a method called the Reverse Image Zero and if the enemy close to within 350 meters, they will switch guns to a Point Blank Zero.

The operators set their guns to an elevation setting for 900 meters. This is the same for the two .50 caliber guns as well as the .338 Lapua rifle. They get word on the SATCOM that the exfiltration aircraft is about 20 minutes out and request a situation report from the team. The team replies that all is secure. Five minutes later, a pair of ZIL trucks pull up with troops. Half of the soldiers began climbing the slope toward their position and the other half goes up the hill away from the team. The team leader orders all three of his guns to pick up targets with the .50s working from the left and right side of the group towards the center and the .338 gun working from the center out of the group. The enemy patrol is moving slow and following the evidence left by the team as they moved up the slope toward the ridge. The team gets word that the aircraft is 6 minutes out. The team leader informs them of their situation and

has the aircraft make their approach from the backside of the ridgeline they are on to mask the aircraft from the enemy unit.

Suddenly, the enemy force picks up their pace and the team leader decides that they will close with the team's position before the aircraft can arrive and provide suppressive firepower with the mini-guns. At a range of 875 meters, all three guns fire a single volley. They do this without determining the range to the targets. When the team opens fire, the enemy troops on the far side of the valley reverse their direction and begin to move toward the friendly position, but they have farther to go. Each time the guns fire, three more soldiers go down. They fire three volleys within 9 seconds taking out 9 troops and leaving only the leader himself. The team leader targets the enemy commander and orders a single 3 shot volley from all three guns. The enemy commander ceases to exist as two 750 gr. tungsten steel bullets and one 300 gr. Matchking bullet tear through him at over 2,500 fps. At that moment the MH-53J Pave low III helicopter pops up over the ridgeline showing his right side and tailgate. Two 7.62mm mini-guns open up with a roar at the remaining troops caught coming down the opposite slope of the valley. The helo drops down and the team jumps onto the tailgate and the bird is down into the valley within seconds.

What method were the snipers able to use to engage targets without finding their range every time they shot? Clearly, they were a good distance down the slope. Any sniper student can remember how difficult it was to range a target that far away with mil relation or even with a laser range finder. These guys were able to look at their data tables and they selected elevation settings based on range, but they also grabbed a setting after consulting their maximum ordinate table. Why did they do this and why no range finding except to get the range to the drop off sight of the enemy troops? Note that they decided to engage with Reverse Image Zero and Point Blank Zero. These methods were covered a little in Chapter 8. Let's look at these two methods.

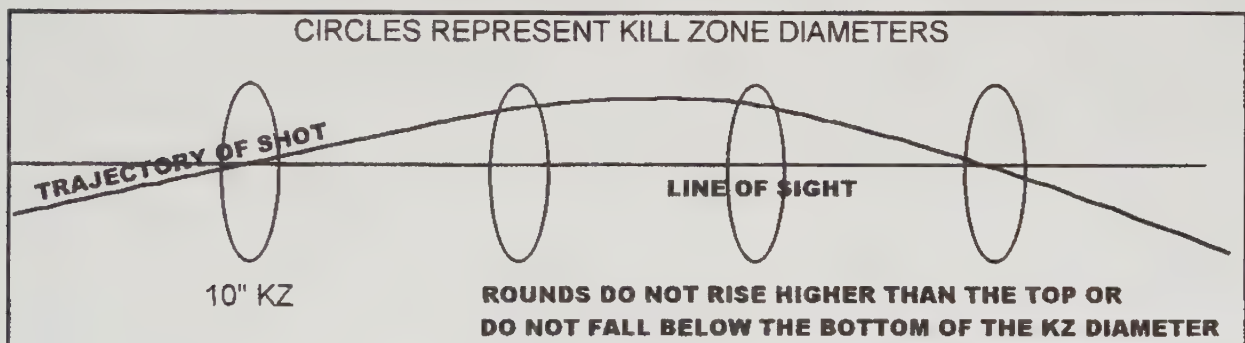
BLACK MAGIC: TRICKS OF TRAJECTORY AND THE POINT BLANK ZERO

Point Blank Zero

Point blank zero is a method of engagement for both materiel and human targets that eliminates the requirement for range estimation to a point. This mid-range engagement technique uses the curve of the trajectory to the shooter's advantage. This method allows the shooter to engage targets by using a center of hold that is the center of the diameters listed under "Kill Zone" in the following table. When the shooter aims at the center of this diameter, he is accepting that the bullet will strike somewhere, vertically, in that size of kill zone. Why are there different kill zones listed?

The different diameter kill zones are presented because shooters have different opinions on what is an acceptable vertical strike area on a human target. Certainly, the tactical situation is also part of this. The elimination of a single, pre-designated target requires a tightly held single shot. If the tactical situation allows the operator to get within 380 meters (personally, I wouldn't want to get that close), range determination isn't required. Other situations allow a little vertical error in the shot placement. The conventional infantry sniper whose job is to simply put soldiers out of action while he is covering his unit's withdrawal can accept shots anywhere from the top of the enemies head to his crotch level. Referring again to the table, the operator using an M-24 with 7.62mm Special Ball ammunition would place a zero or an elevation setting of "4" plus 4 minutes on the scope. He then aims halfway up from the crotch to the top of the head out to a range of 560 meters. The round will strike somewhere within that 1 meter frame. At nearer ranges, the round will strike above the point of aim. At a range of about 500 meters, the round will impact on the target below the point of aim.

POINT BLANK ZERO DATA FOR 6 TACTICAL LOADS					
M118 Special Ball 7.62mm @ 2600 fps			300 W Mag. A-191 190 gr. MK @ 3000 fps		
" Kill Zone	Zero At	Max Range	" Kill Zone	Zero At	Max Range
10"	275 M	324 M	10"	319 M	373 M
15"	323 M	382 M	15"	372 M	439 M
24"	392 M	463 M	24"	450 M	531 M
1 Meter	470 M	564 M	1 Meter	550 M	650 M
338 Lapua 300 gr. MK @ 2850 fps			338 Lapua 250 gr. Lapua @ 3000 fps		
" Kill Zone	Zero At	Max Range	" Kill Zone	Zero At	Max Range
10"	310 M	364M	10"	323 M	380 M
15"	363 M	429 M	15"	380 M	447 M
24"	442 M	525 M	24"	458 M	542 M
1 Meter	550 M	650 M	1 Meter	563 M	665 M
50 Cal. Mark 211, Mod-0 @ 2840 fps			50 Cal. M-903 SLAP (350 gr.) @ 3950 fps		
" Kill Zone	Zero At	Max Range	" Kill Zone	Zero At	Max Range
10"	302 M	356 M	10"	431 M	510 M
15"	355 M	420 M	15"	509 M	604 M
24"	431 M	509 M	24"	621 M	738 M
1 Meter	528 M	623 M	1 Meter	768 M	910 M



Here are some possible scenarios for the use of Point Blank Zero. Some of these apply to anti-personnel sniper operations and others apply to the use of heavy rifles and anti-materiel sniper operations.

- Patrolling to a Target Area.** A sniper team is en route to their target area. While they were in mission planning, the team analyzed the terrain and the vegetation in the area from the point of infiltration to the target area. The terrain is hilly with some canalization. The trees and underbrush are said to allow for about 50 meters of unrestricted vision during the day. There are times when the team will be crossing terrain that allows their line of sight to go for about 400 meters. This means that they can also be seen for 400 meters. The team will place a Point Blank Zero for a Kill Zone diameter of 1 meter on their gun. They have a .300 Winchester Magnum and a 7.62mm gas operated support weapon. The operator carrying the .300 magnum puts a zero on his gun for 450 meters. This allows him to place his crosshair in the center mass of a threat that shows up anywhere from his barrel to 531 meters and he will strike it within a 24-inch bracket on the target. The operator carrying the 7.62mm gun places a zero of "4" on the bullet drop compensator of his gun. This allows him to engage targets to 450 meters with a center hold for elevation.

In both cases the shooters have the option to switch their zeros to 500 meters. This will allow them more range to hit targets but as you see in the table on page 299 these rounds will strike somewhere between the crotch and the top of the head of the enemy target (1 meter bracket).

- Conventional Use of Snipers in a Defensive Position.** An infantry company is in a defensive position. The position is laid out with interlocking fields of fire and machine gun support on key avenues of approach and covering weak spots. Their final protective fires are laid in and ready. The snipers are being used initially as Observation Posts on high points that are far in front of the U.S. forces. Their job is to locate the enemy and identify key targets within the enemy force. The terrain in the area is limited and the best line of sight for the snipers is about 500 meters. Their task is to observe and report the enemy situation. On approval, they are to engage enemy commanders and radio operators with long range fire. They will then fall back into positions within the company perimeter. They know that the enemy forces will be moving in a tactical formation that may have a depth of 150-200 meters. Using a point blank zero for a kill zone diameter of 24 inches allows them to engage to a range of 550 meters without range determination. They can use the map to get a rough range as to when they can engage. Mil relation is accurate enough to support point blank zero fire. All they have to do is confirm that the enemy is higher than 2 mils from the head to their crotch and they are within 500 meters. As the enemy moves in range. A coordinated fire between the companies' 6 snipers drops 4 possible officers and 2 radio operators. The snipers pick out 4 more targets then move into the company perimeter. Once in the perimeter they prepare to engage priority targets in support of the main defense. The farthest range they can see is 350 meters. By setting a range of "3" plus 1 MOA on their M-24s, they can kill targets out to a range of 380 meters by aiming center mass and the rounds will strike within a 15-inch circle on the targets.
- Sniper Support/Security for a Sniper Team.** A sniper is part of a sniper team whose mission is the elimination of a single key individual. The sniper team has the mission to eliminate a key enemy officer that has heavy security in depth. The snipers arrive in the target area that has a trail that comes straight at the team and the crosses in front of them. This trail is the expected avenue of approach for the target. The lay of the terrain and the nature of the target suggest that the target's security have a good chance of detecting the general location of the team when the primary sniper takes his target down. They decide that simultaneous precision fire from two of the support snipers take out as much of the security as possible when the primary target goes down. They lay in the range to the target using triangulation that was covered in Chapter 7. The range is 600 meters. In this manner, the primary sniper will ambush his target as that target crosses this "range mark." The team is shooting downhill on about a 15 degree angle. This gives them a range corrected for an angle of 579 meters. The primary shooter is armed with a .338 Lapua Magnum. The support shooters have two 7.62mm gas-operated guns. The team decides that they can accept hits on their security people anywhere within a 1 meter bracket. Referring to the table on page 299



they fix an elevation of "5" minus 1 MOA of their Mark IV, M3A scopes. This gives them a zero range of 480 meters. With a 1 meter target size, they can hit targets to a range of 564 meters with a center hold. For targets a little farther back, they simply shift their point of aim to the head and let the rounds fall into the chest of the deeper targets. The target appears down the trail and is walking/patrolling into the kill zone. The point security is a good 100 meters in front of the intended target. This is good news for the security shooters as their targets will be well within their Point Blank Zero ranges. There are 2 point men, and then the nearest security is the direct protection for their intended target. They are located about 2 meters on either side of the target. The rest of the patrol will have to be dealt with as time and the situation allows. There is no fire support. As the target crosses the primary shooter's mark, the .338 booms and one 300 grain round goes through the high chest of that target, instantly dropping him. At the same time, the support operators pick up the center mass of the point men in the patrol. They fire simultaneously and those two men drop. The support snipers immediately shift their point of aim to the security men moving toward their position. They hold center mass on these targets that are as yet, at an unknown distance. The two targets drop with rounds high in their chest. The .338 and the two support guns each pick up a target apiece and the enemy patrol breaks contact and moves back out of visual range. The nearest living threat is 700 meters away. A total of six targets were engaged with only one being precisely ranged and deliberately engaged. The remaining targets were not of threat or opportunity in nature.

- **Steel Hunting.** A Hard-Target Interdiction team is given the mission of infiltrating an area and locating a mobile SCUD missile site. In their data book, they have this page out of the .50 caliber shooting tables. This table has the critical target sizes for the all types of .50 cal. ammunition. The height of target can also mean a component of any target. For example, a critical part of a target is 2 meters tall. By putting a zero for 600 meters on the gun, the shooter can hit that critical component within the 2 meter target area out to a range of 700 meters without precise range determination. Back to the scenario. In mission planning, the team determines that they may get a visual line of sight out to a range of 1,500 meters depending on their and the target's location on the ground. They check their targeting books and find that a SCUD missile is 11.5 meters tall. The

POINT BLANK ZERO TABLE // .50 CAL. SWS

THIS POINT BLANK ZERO TABLE IS FOR FAST AND LESS THAN PRECISE ENGAGEMENT OF TARGETS LISTED BY THEIR HEIGHT. THIS TABLE IS FOR ALL AMMUNITION IN THIS DATA BOOK EXCEPT FOR M-903 SLAP

EXAMPLE: SCUD B MISSILES = 11.5 METERS LONG (ERECTED)

TO PLACE A SHOT ANYWHERE VERTICALLY ON THE MISSILE BODY, PLACE AN ELEVATION OF 36.75 MOA (1100M). MISSILES OUT TO A RANGE OF 1253 METERS (SAC) A ROUND WILL STRIKE SOMEWHERE BETWEEN THE TOP AND THE BOTTOM OF THE TARGET. OTHERWISE KNOWN AS "SNAPSHOOTING"

HEIGHT OF TARGET	ZERO RANGE	PB ZERO RANGE
1 Meter	457 M	530 M
2 Meters	600 M	700 M
3 Meters	700 M	813 M
4 Meters	777 M	900 M
5 Meters	841 M	970 M
6 Meters	900 M	1035 M
7 Meters	950 M	1088 M
8 Meters	990 M	1125 M
9 Meters	1033 M	1170 M
10 Meters	1070 M	1216 M
11 Meters	1100 M	1253 M
12 Meters	1134 M	1290 M
13 Meters	1161 M	1325 M
14 Meters	1188 M	1363 M
15 Meters	1216 M	1390 M

THIS METHOD WORKS WELL WHEN THERE ISN'T ENOUGH TIME TO PERFORM RANGE FINDING AND CRITICAL CALCULATIONS.

mission is critical in that enemy forces have threatened to launch a biological warhead. The team knows that mobile launchers can stop and set up in a short period of time and that precision range finding may not be an option. SCUD missiles are fragile and they cannot sustain a .50 caliber hit anywhere on the missile body and continue to be operational. The team refers to the table above and goes to the line for an 11 meter tall target. They see the zero range to be 1,100 meters or 42.75 MOA elevation setting. They can now hit a target out to a range of 1,253 meters without range determination. By using a quick mil relation formula, they can assess if the target is farther away than 1,250 meters. In that case, they shift their point of aim to the top of the target instead of the center mass. By shifting straight to the top, they know that they won't fly over the target because of the long range trajectory. Shifting to the top of the target gives them another 150 meters or so of engagement range without range determination. When the team gets on the ground, they will determine the effect of MET and ENV conditions and apply these to the sight setting. At that point, they may gain some additional range or lose some range depending if the temperature is high or low and if the pressure is high or low. The effect of slant angle is possible because in their terrain analysis, they determined that some of the ridgeline to valley shots is on as much as a 12 degree angle.

- **Fire Support.** A Ranger Company is given the task of seizing and securing a small airfield. Three sniper teams are assigned points of domination on the airfield. Their two primary tasks are to eliminate threat personnel and to keep any aircraft from leaving the airfield. Each 2-man team has a .50 caliber sniper rifle and a 7.62mm gas-operated support gun. Due to the dynamic nature of the seizure, range finding operations won't be possible or practical while the seizure is going down. The snipers need a method to engage targets in support of their troops quickly and efficiently. The Rangers have airfield imagery that allows them to get rough distances from the assigned points of domination to "range bands" 360 degrees around those points. In mission planning, they work up a pre-made range card that they can use to quick reference ranges to targets. The three points of domination have overlapping fields that require no shots longer than 400 meters from any one sniper position.

Referring to the data on page 299, the snipers accept a 1 meter kill zone for the 7.62mm guns and will put a zero on the gun for 470 meters ("5" – 2 MOA on the M3A Ultra scope). For the .50 caliber rifles they accept a 2 meter kill zone based on the height of the helicopters and jet aircraft that they may have to interdict. They place a zero setting for 600 meters (17.50 MOA) on the guns. At the short range that they are covering, they could also go with a 1 meter bracket and be more precise. At these short ranges any slant angle will be of little effect and the



An SS-25 mobile launcher.

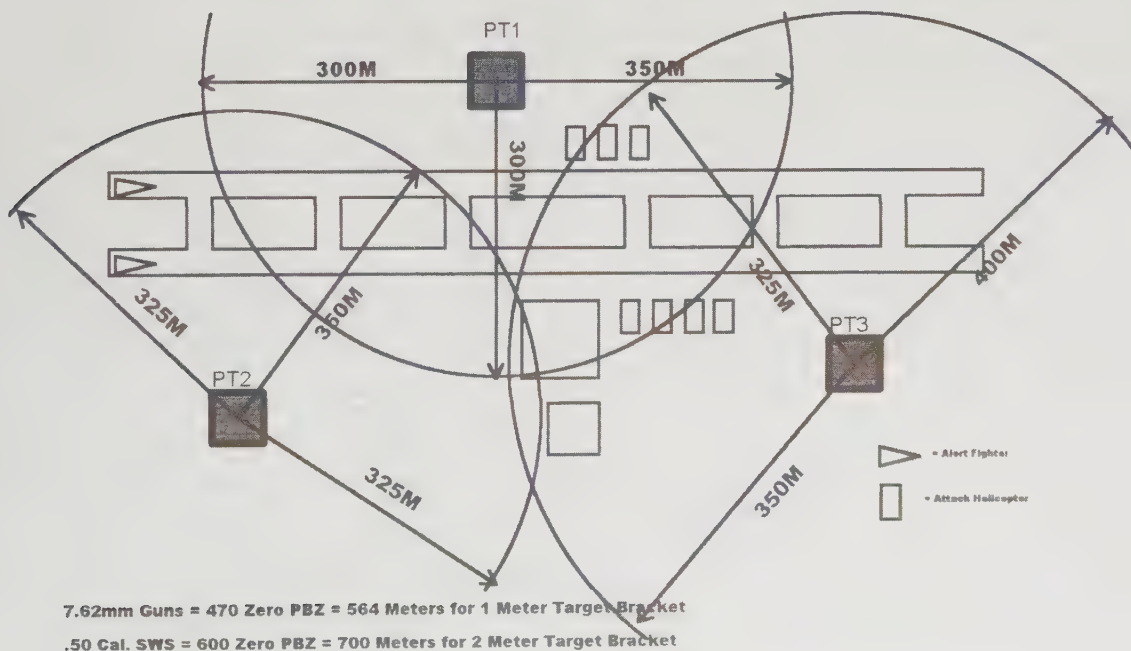
APPLICATION OF FIRE

corrections needed for MET and ENV conditions won't apply. This scenario is about engaging targets with precision that a machine gun team can't do because of the high probability that friendly U.S. forces will be downrange from the sniper's fire. The sniper's precision allows support fire to continue without having to lift and shift fire.

The Ranger Company does a low level parachute jump onto the airfield. Three days earlier the sniper teams had infiltrated the area and set up surveillance on the airfield. Tactical information was transmitted through a satellite radio to the unit headquarters in the rear area. Not counted into the equation, but discovered by the sniper teams was the presence of two ZSU/23-4 23mm tracked anti-aircraft gun systems. These were located at either end of the airstrip. When the pilots could see the leading edges of the airfield, the snipers engaged these gun systems with armor piercing, explosive tipped ammunition and took them out of actions with three shots each. This eliminated the biggest threat to the aircraft themselves. As the jump is going down, the snipers suppress targets that are of immediate threat to the parachute assault operation. On a pre-arranged star-cluster signal the snipers break from their position and move to their points of domination as depicted in the drawing below. The sniper teams at PT1 and PT2 immediately engage the two alert fighter aircraft with .50-caliber fire. They fear the enemy might try to take out the C-130s that deposited the Rangers as retaliation. Snipers at PT3 engage the helicopters with .50-caliber fire to eliminate that response threat. As the operation continues the snipers use their smaller 7.62mm guns to engage enemy threats until they get the command or signal that the objective is secure.

When this objective is secure the snipers then turn their attention to alternate fields of fire that are facing out of the airfield perimeter. Their mission becomes one of observing and reporting on any enemy troops that might try to counterattack the company. These sniper teams will enhance blocking positions that the Ranger company has set up on high speed avenues of approach into the target area. Their dominating fields of observation allow for the best overall surveillance of the airfield and the surrounding woods and fields.

The above scenarios are intended to supplement the material that describes Point Blank Zero. The use of scenarios helps the reader understand in what ways these methods can be used. The concept of point blank zero is easy to understand, but it is sometimes more difficult to apply the theory. It is suggested that you



practice this method of known distance ranges to understand the relationship of the trajectory to the different diameter kill zones. Practice it on the unknown distance ranges to give yourself confidence that the method works. It is good if the commanders and bosses can observe these methods as many leaders know that range determination causes huge problems with very dynamic and fast moving operations. The commanders need to see that snipers can support their operations without the danger of hitting friendly troops while they are engaging the enemy threat.

BLACK MAGIC: TRICKS OF TRAJECTORY / THE REVERSE IMAGE ZERO

The Point Blank Zero and the Reverse Image Zero are two methods of engagement that use the dimensions of the trajectory to engage targets of unknown distance without determining that distance first. The concept of the Reverse Image Zero isn't all that new. It was only recently rediscovered and modified to apply to modern rifles with better trajectory performance. In the earliest reference that I could locate to the concept of Reverse Image Zero (referred to as negative angle sighting in *The Theory of the Rifle and Rifle Shooting*) Lt. H. Ommundsen advanced the idea of a negative angle sighting toward the beginning of 1912. Sir George Greenhill advocated it in a lecture at the Institution of Electrical Engineers on January 19, 1912.

"With a certain rifle and ammunition select a trajectory, the greatest height of which is twice that of the target desired to hit. For instance, with the service short rifle and Mark VII ammunition an 11 foot high trajectory (that is to say, a trajectory, the maximum ordinate of which is twice the height of an average man) is given with a range of something under 700 yards. Using the combination of rifle and ammunition mentioned, this would be the trajectory selected for the negative angle sight."

The rifle and ammunition that the author in the above document is referring to is the .303 Enfield rifle. The concept is that the shooter looks at his target downrange. He then mentally projects where the top of the head of the mirror image of that target would be. As noted in the material, the trajectory selected is for twice the height of the target. The standard target height was a 6-foot-tall man. The trajectory for the .303 Enfield that is roughly double that 6-foot-tall man is the maximum ordinate for 700 yards. The shooter placed a setting on his iron sight for 700 yards. Then by aiming at the head of the reverse image of the target, the round will not be higher than the height of the human target downrange.

When the shooter aims at the reverse image of his target's head, this lowers the overall trajectory so that the maximum ordinate occurs at the same point downrange, but that ordinate is half the normal distance above the ground level. The shooter is actually aiming at a point below the target the same distance the target is tall. The point of aim for a 6-foot man is six feet below that man's boot level. For those of you that have tried to lead a target with an optical sight you can image how tough a holdoff would be with the iron sights of the time. Imagine trying to put a front sight post on a precision point that is 6 feet below a target—and you may not be able to see the entire target. This is the case in most field shooting environments. A target in the field that is camouflaged and has very little contrast is going to be very difficult to identify with the naked eye at 700 yards. Add to the problem of target identification and sight alignment, the problem common with open sights. These problems include glare on the post and the rear sight, difficulty in alignment of the sights with a target that is very difficult to see and probably holding off for some wind.

Everything I have been able to find indicates that this method was not adapted as a standard training method. It is understandable why that is. However, with modern firearms, the power of the cartridges and optical sights, the formula becomes a bit easier to manipulate. We will use the cartridge used by the standard military sniper, the M118 Special Ball round for analysis of this method.

To introduce this method we will again refer to the range of 700 meters as was mentioned in the early text in 1912. The first difference to note is that we are dealing with 700 meters. This is because the bullet drop compensator used on the M-24 system is graduated in hundreds of meters. The following ballistic facts are presented:



**Point of Aim for iron sights
was 6' below the bottom of the
visible target.
Max. Ord. was 12' for a 700
yard zero.**



- The Maximum Ordinate for the .303 Enfield round at 700 yards is 11 feet 6 inches above line of sight.
- The Maximum Ordinate for the 7.62mm Special Ball round at 700 meters is 73 inches above line of sight.

There is a huge difference in the ballistic trajectory between the cartridge of 1912 and the sniper cartridge in current use. The maximum ordinate for the M118 round is almost exactly half that of the .303 round. How is this significant? The shooters that had the .303 round and iron sights had the problems mentioned above. Those being: targets difficult to see and identify clearly, iron sights, and windage holdoff problems. Current snipers have precision optical aiming instruments that allow them to see the target much more clearly than with iron sights. This is significant because with the maximum ordinate being only 6 feet and the target size being 6 feet, the bullet never rises above the target's height from a range of 0 meters to a range of 700 meters.

The next image depicts the trajectory and its approximate points of strike on targets between 100 and 700 meters. As you can see, there is a danger point in the range where the round at 400 meters is at its highest point in the flight. The round at 400 meters will strike in the head area. This is the narrowest part of the target and observers must be aware of the subtlest winds when targets are around 400 meters. One way to deal with this is to give windage data to the shooter for 400-meter winds and let the shooter determine if the target is in that danger zone. He then applies the wind as he feels fit based on the range to the target.

The good thing about this technique is that it isn't at all limited to any one cartridge or range for that matter. The size of your target or a part of that target only limits it. Refer to the

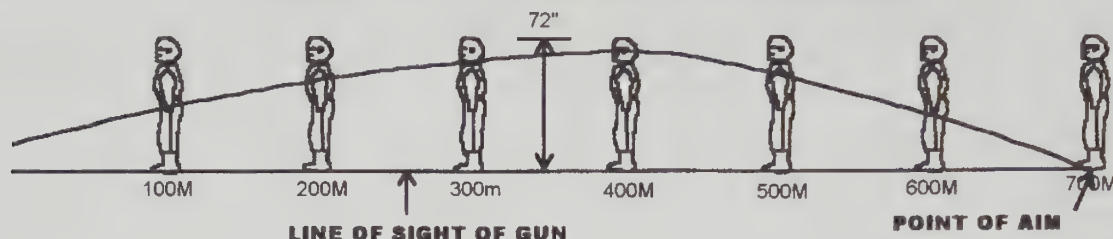
BALLISTIC DATA

M118 SPECIAL BALL 7.62mm @ 2600 FPS

RANGE	FALL ANGLE	FLIGHT TIME	MAX.ORD INCHES	MAX.ORD. FEET	REMAIN VELOCITY	SPIN DRIFT IN. (MOA)
100M	.04846	.13172	0.8080	.06734	2370	.041 (0.00)
200M	.11178	.27445	3.6260	.30217	2182	.184 (0.00)
300M	.18754	.43013	8.8678	.73899	2004	.451 (0.00)
400M	.27242	.60076	16.659	1.3883	1812	.851 (0.00)
500M	.40744	.78867	30.153	2.5127	1648	1.547 (0.25)
600M	.55558	.99736	48.128	4.0107	1497	2.472 (0.50)
700M	.76058	1.2323	73.577	6.1314	1361	3.825 (0.50)
800M	1.0343	1.5041	110.23	9.1857	1243	5.773 (0.75)
900M	1.3628	1.7978	159.27	13.272	1150	8.368 (0.75)
1000M	1.7481	2.1141	223.92	18.660	1079	11.73 (1.00)
1100M	2.3422	2.5333	329.42	27.452	1024	17.02 (1.25)

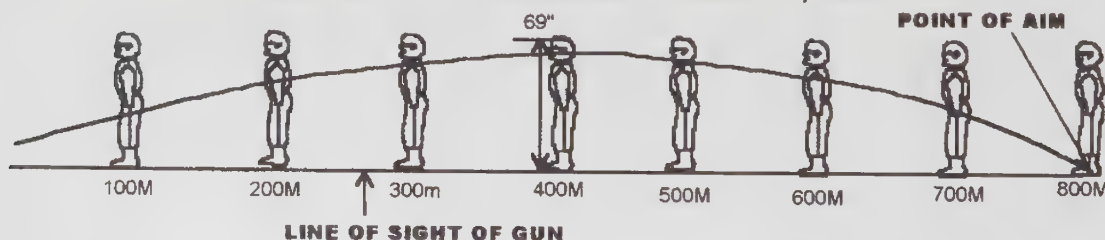
.50 caliber Mark 211, Mod-0 ammunition table in Chapter 6. Look at the column for Maximum Ordinate in Feet. Trace down that column under you find the first elevation that is nearest to, but not more than 6 feet. The range for that maximum ordinate is 800 meters. If you set a sight setting of 25.50 MOA for 800 meters and hold at the bottom or feet of the target downrange, you will put a round through that target as long as he is somewhere between 100 and 750 meters. At ranges past 750 meters, the rounds are below knee height. In this case, the maximum ordinate is slightly lower than for M118 ammunition, and you gain another 100 meters in killing range without ever determining the range to the target.

TRAJECTORY PATH FOR 700M SHOT // M118 Special Ball



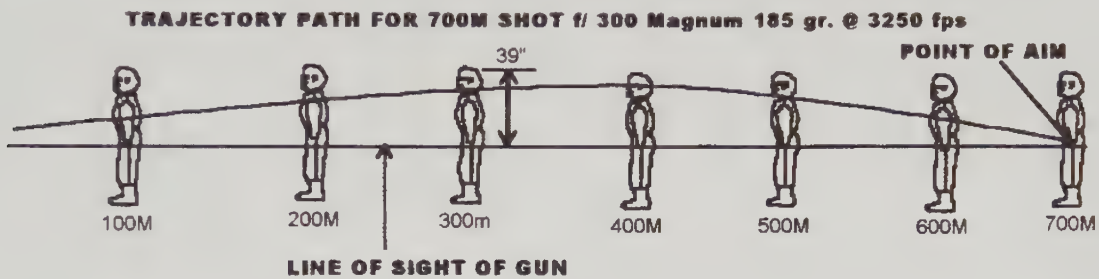
There is another method that can be used if you have a very high performance flat shooting rifle. In this example, a .300 Winchester Magnum shooting a 185 Grain Lapua Match bullet at 3,250 fps is used. In this case, we are only going to use a portion of the human target frame. We are going to shift our point of aim from the feet to something more easily seen and located on the target. That is the crotch of the target. With this load, we have a very flat trajectory. The trajectory is very flat for a distance of 700 meters and this allows us to rise our point of aim to the crotch level. We would do this because our targets are not expected to be presented past 650 meters or so. A flash mil reading that shows the target to be of a greater value than 1.5 mils confirms that the target is within 666 meters. This method works so much faster because the shooter and observer both know that the scope is set for a Reverse Image Zero condition. They both know the point of aim and the maximum range that they can engage targets. The team can do a precise range determination on the ground using triangulation to a non-specific point on the earth. Whenever a target pops up anywhere between the team and that pre-ranged point on the ground, they simply hold on the crotch and the observer gives a wind call for a range he thinks is close to the target. The whole time from spotting the target to the first shot going downrange is 6 seconds or faster depending on the team's experience in this method. That is much quicker than some school's standard of 1 minute from the time the observer starts talking the shooter onto the target till the time the first shot goes off.

TRAJECTORY PATH FOR 800M SHOT // Mark 211, Mod-0



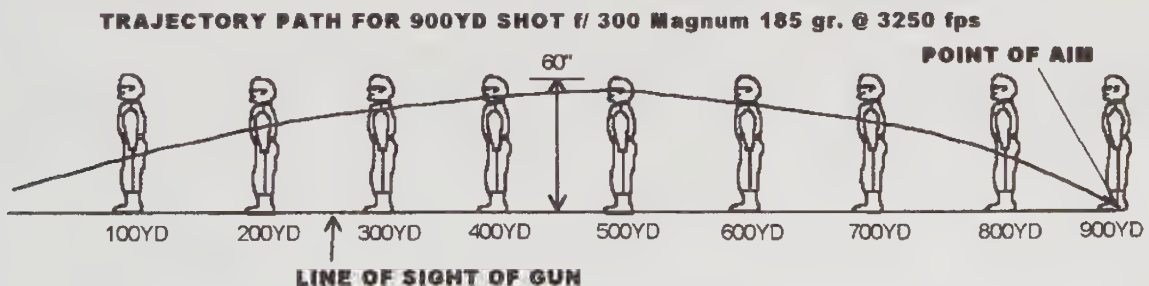
This 300 Magnum load has a powerful and flat trajectory. If the operator wants to push his range out further, he can drop his point of aim to the bottom of the target and the trajectory still stays below the top of the target's head (maximum ordinate = 60 inches). You will be able to engage targets with disabling and killing shots to a range of 850 yards.

The Reverse Image Zero is quite a bit different from the original concept that was presented in 1912 by Lt. Ommundsen. The theory was a good and sound one that is very difficult to execute with iron sights even when using cartridges of the power mentioned above. The big technology boost that changed all of that was the advent of optical sights. One can easily expand on the methodology. Imagine that you are training snipers overseas and those snipers don't have optical sights with bullet drop compensators or target elevation and windage knobs of the Leupold & Stevens Mark IV, M3 or M1 design. There are many countries with sniper rifles with standard hunting scopes. By analyzing their terrain, tactical situation and the sizes of their adversary targets you can determine what is a good reverse image zero range for that area.



If I were in SE Asia as a sniper with a 7.62mm rifle and the average shot range were only 500 meters, I might zero the gun dead on at 550 meters. By aiming at the waist of the target, I will be able to hit all targets between my barrel and 500 meters downrange. For the longer range shots, I'd do what I would do with any other weapon—I'd get an accurate range and make a precision engagement.

Throughout this whole section on Point Blank Zero and Reverse Image Zero you may have been wondering why I put so much emphasis on precise range determination methods in Chapter 7. The methods that are mentioned here are intended to eliminate the need to obtain an accurate range on targets when there is little time, or the target doesn't need a 2 MOA engagement to kill him, maybe only put him out of action. These methods are meant to offer a means to engage targets that may surprise the sniper team en route to a target, or provide them with the ability to engage multiple targets of depth as part of an overall larger plan. There is no further need to manipulate the sights as with precision range finding. The interesting part to me was, with all the emphasis on mil relation; the Reverse Image Zero works on the ranges at which mil relation is only any good for. The RIZ negates the use of mil relation.



Yes, I mentioned doing a "flash mil" to ensure that a target is within engagement range for either the Point Blank Zero or the Reverse Image Zero. The mil reticle is a great thing for some things—I just don't subscribe to its use as a precision ranging tool on human targets. For materiel targets of great size it works fine at times, as long as the target isn't moving.

The methods above were presented in the context of engaging human targets. The same methodology works on materiel targets. The ranges are definitely longer and you must pre-determine your corrections for



The range span of the targets in this photo and the village huts in the valley below is about 600 meters. By using the reverse image zero technique a sniper could engage targets on the hill at the near range and immediately switch to targets in the valley at the huts, and not ever touch the elevation knob. The point of aim is at the feet with elevation setting of 700 meters.

MET and ENV conditions. There is an interesting phenomenon that occurs when using these techniques with other than standard atmospheric conditions. When you are using the PBZ or the RIZ method the effects of MET and ENV conditions can either aid you or hinder you in hitting targets of unknown distance. Imagine that you are using a Reverse Image Zero method and are holding on the bottom of the target. The barometric pressure is around 30.50 and the temperature is low at 35 degrees F. Both of the MET conditions are situations that cause increases drag on the bullet. This shortens the trajectory and if your target is in the last 75 percent of the trajectory, the round will fall short.

The opposite is true if the conditions are in a "gain range" situation. Imagine that you are at 5,000 feet ASL and the air temperature is 75 degrees. In that case, the MET conditions are favorable to extending and lowering the shape of the trajectory. In that case, instead of using the RIZ to hit a target at 1,200 meters, your range will be extended to about 1,350 meters for the same hold on the same target with the same elevation setting.

These methods are offered as an advanced application of sniper fire. This author has little faith in mil relation on all but non-moving and/or large targets. Another factor that is little mentioned when milling a target is the effect that a mirage has on the appearance of that target downrange.

WINDS

There is enough material about reading and doping the winds to choke an elephant. However, most of the information that is written about winds are about the winds that occur during competition (maximum range of 1,000 yards) or that occur on ranges of conventional sniper operations (600-800 meters).

There are a couple of camps of thought when it comes to where to read the winds when doping them. One camp reads the winds at the gun only. The theory in that is that when there is a wind blowing at the gun's position, the bullet immediately picks up a cross range sideways velocity that continues all the way to the target. Well, I happen to agree with that. However, when you are shooting in excess of 1,000 yards or meters, and for shorter ranges than that, there can be counterwinds downrange that can easily offset the value of the winds at the gun.

Admittedly, the art of reading the wind when it comes to 1,600 meter shooting is a fair amount of luck, some guessing and some application of the scientific calculator. The technical corrections for the effects of air temperature on the winds are found in Chapter 6. There aren't any magical solutions for determining these winds. With some careful mission planning and if the tactical situation allows it, the sniper teams can place themselves on the dominant wind line, or somewhere close to it. The terrain has a lot to do with how the wind flows across the ground. The wide open spaces of the desert or the plains of the Dakotas allow for some pretty consistent wind directions. If you are in the hills however, these winds suddenly change and at times come from different directions all at the same time.

We are going to break the wind down into three categories. These categories are based on the location where we are going to read the winds. The categories are:

- Winds at the Gun Position.
- Winds Between the Gun and the Target
- Winds at the Target



Twenty-three knot winds from about 100 degrees magnetic to the gun target line.

Winds at the Gun Position

The winds at the position are the first wind that the sniper feels. He may be in a position, however, that does not allow him to feel any wind at all. Competition shooters place a lot of value on the winds at the gun. If the terrain is pretty flat and is the shape that allows even wind flow across the ground, these winds are the best indicator of the winds that are downrange. Here in central North Dakota, the winds are pretty much even across the surface of the ground. That doesn't mean that the speed is steady. It just means that the winds at the gun are usually the same as the winds that are downrange.

A problem arises when we shoot at a very long range and the trajectory of the shot has a maximum ordinate that is

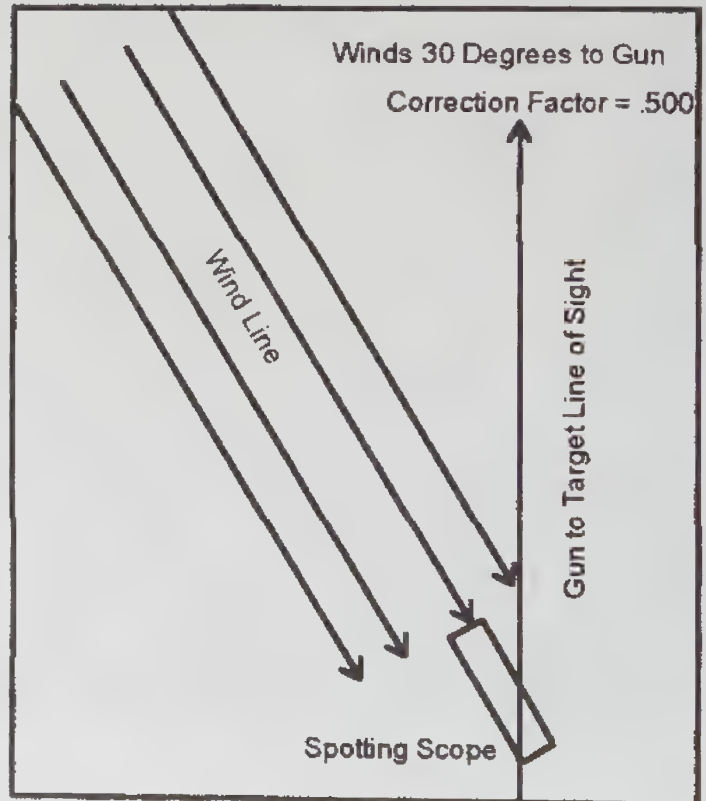
very high in the sky. For example, a shot at 1,500 meters with Mark 211, Mod-0 ammunition has a maximum ordinate of 40 feet above the line of sight. To assume that the winds are the same “up there” could cause a problem. Once you get the velocity of the wind at your position you must determine its true value to the flight of the bullet. The wind may not be blowing at a 90 degree angle to the gun. But before we get into that, let’s look at the next “bracket” of wind value.

Winds Between the Gun and the Target

At SOTIC we used to train the shooters to determine the wind value for about two-thirds the distance to the target. That method works fine for most applications where the fire is less than 800 meters. For extreme range shooting we are going to modify that a little bit. We want to read the winds at the range at which the maximum ordinate occurs. This is usually about 60 percent of the range to the target. The other reason is that when the bullet is “up there” the winds are frequently higher than they are on the ground. As the wind moves across the ground, the earth causes some drag and slows the wind down. This is especially true when the wind is flowing across hills and gullies, up and over trees, and through the shrubs and bushes. The bullet doesn’t fly through these trees. It might at first, but I guarantee you when you are shooting 1,600 meters, that bullet gets up in the wind eventually. So how do we read the winds “up there?”

First, focus your spotting scope at the range at which you want to read the winds. You may or may not see the mirage at that point. Slightly unfocus your scope by turning the focusing ring counterclockwise. This improves the ability to see the mirage. At times the mirage is very thin also. Another eyeball trick is to close both eyes behind the spotting scope and then quickly open your eye behind the scope. For a second or so, you will be able to see the mirage good until it fades. Once you have obtained the mirage at your desired range, elevate the scope above the target point to an elevation above the ground that you think is near the maximum ordinate (40 feet based on the example below). If you have terrain behind the aiming point at that elevation you should be able to see the mirage clearly. Chances are that the mirage is also moving faster at that altitude above the line of sight.

Assume that you have assigned a windage value to that mirage. Now you want to determine the windage direction. We know that the velocity picks up and drops off constantly during the day. The direction takes a bit longer to take a change. To determine the wind direction turn your spotting scope left or right, looking through the scope the whole time. As you turn the scope, you will suddenly get a boiling mirage. Take a look at your spotting scope’s angle in relation to the gun target line. A protractor laying along the side of the scope on the ground will give you the angle of the scope. Remember, we know that the wind velocity is going to change. The most important thing at this point is to determine its direction. Once the direction is established, we go back to the wind value by swinging the spotting scope back to the target. Note: When you assign wind value in MPH to a mirage you



are correcting automatically for the wind angle in relation to the gun-target line. You only need to calculate for wind angle when you are using anemometers or other visual methods of determining wind and direction.

This may seem like it is taking a long time. It does, but that shouldn't be a problem since you want to be in the target area in enough time to do an assessment of the MET and ENV conditions. On a piece of paper, write down your dominant wind direction at this range. You should have wind speeds and directions for two different points on the range now.

Winds at the Target

Arguably, the winds at the target may or may not mean anything. I choose to acknowledge them. Some opinion stands that says winds don't mean anything, because the bullet is impacting there so how can the effect of the winds mean anything there? The reason for assessing the wind at the target is to gather wind data at three points downrange and get an average of these velocities and directions. You get the wind speed and direction at this point the same way that you do in the technique mentioned above. Write down the velocity and more importantly the direction. Now we are going to assess the value of these winds. We have three wind "bands" to determine the corrected velocity for. Remember, this method may seem long but this is done long before the shot goes off and really is used to determine the direction and relative effectiveness of the winds on your shot.

- At Target: 10 mph from 60 degree angle X .866 = 8.66 kts. effective winds
- At maximum ordinate: 12 mph from 70 degree angle X .940 = 11.5 kts. effective winds
- At the Gun: 14 mph from 40 degree angle X .707 = 9.9 kts. effective winds

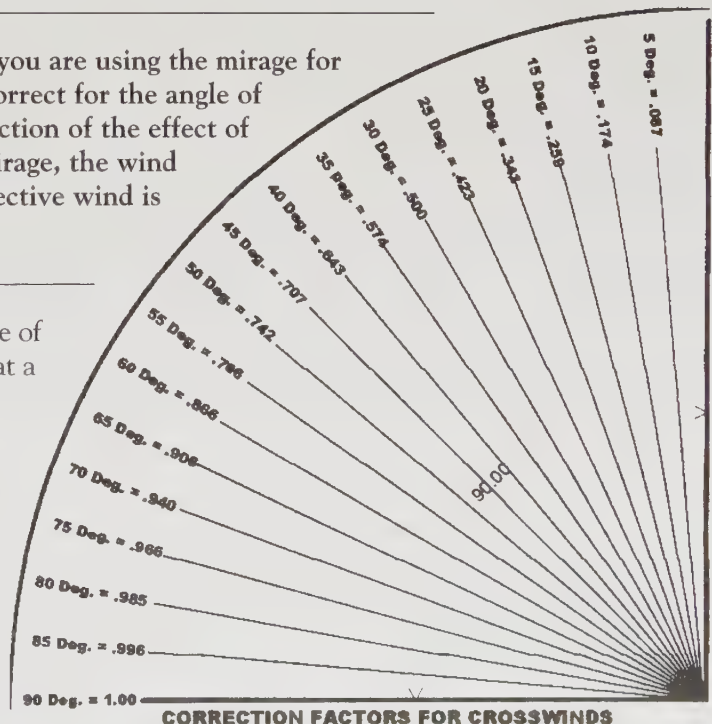
Take an average of all three readings. Total effective winds for shot = 10 mph across the range.

With this average speed of 10 mph you can go to your windage data sheet and get the MOA setting for 10 mph. 1,500 meters = 13.00 MOA for Standard Atmospheric Conditions. Remember that a cold wind blows the bullet harder than does a warm wind. This factor must be corrected for also. For example if the air temperature was 40 degrees F. that 13.00 MOA setting would become 13.75 MOA.

NOTE: Again let me emphasize that when you are using the mirage for determining the wind velocity, you **DO NOT** correct for the angle of the wind. The mirage, when seen, is a true depiction of the effect of the wind. That's why when there is a boiling mirage, the wind may still be blowing 10 mph (example) but the effective wind is 0 mph because it is on the gun-target line.

That might not be significant based on the size of your target or intended point of attack. Shooting at a human target though? It means a miss and don't forget to add in the spin drift correction of 1.25 MOA.

At times the winds can be going in opposite directions. You may have winds at the gun from left to right. At the mid range they may be right to left and at the target, they're left to right again. How do we handle this? When you add all three wind values together, make the winds



that are from the opposite direction (mid range) a negative number on your calculator. As you add all three together and average them, the opposite wind direction is figured into the equation.

- Winds at the Gun: L – R winds @ 14 mph at 40 degree angle = 9.89 effective wind.
- Winds at Max. Ord.: R – L winds @ 12 mph at 70 degree angle = -11.28 effective wind.
- Winds at the Target: L – R winds @ 10 mph at 60 degree angle = 8.66 effective wind.
- $9.89 + -11.28 + 8.66 = 7.278 \div 3 = 2.43$ mph Left to Right average for 1,500 meters.

Winds that come from the 12 o'clock or the 6 o'clock position also have an effect on the bullet's flight. Since the winds rarely stay on a precise direction for any period of time, these winds tend to switch back and forth, called "fishtailing" winds. These winds require frequent windage corrections when firing a string of shots. In a tactical situation, the observer is going to have a tough time determining which wind value is going to have the most effect on the bullets over the long range. The flight times that we are talking about when shooting 1,500+ meters are 3 seconds or more. Are the winds stable for that period of time? If not, what is the effect going to be at the target? These are very tough questions. The observer is going to have to determine the rough stability time of the wind and at what speed that stabilized wind is blowing at.

Wind does have a most stabilized wind speed and direction. The winds are a function of the temperature of the atmosphere and the earth heating up and cooling down. While the wind does change speed and direction, there is always a more stabilized wind speed and direction. Once the sniper team arrives in their target area, they must constantly do a meteorological assessment that determines the air pressure, temperature and the wind data. Used in combination with some weather intelligence you can effectively gather the wind data over a 2 day period (the longer the better) and with some accuracy know what the "dominant winds" are going to be at the time of the shot. Not all sniper teams are going to have the opportunity to arrive in their target early enough to gather wind data. They will have to do the best that they can to assess the winds at the time of the shot, or in the little time they have before the shot.

Wind analysis is not something that you do in the moments before the shot. Start gathering the wind data as soon as possible. Many times the vegetation will give some indication as to the wind direction and velocity in the area. Winds that blow constantly from a direction will cause the vegetation to lean with the wind. The vegetation will eventually grow with that lean. Remember that the wind that is blowing across the surface at ground level is going to be slower and probably a different direction than the winds that are at maximum ordinate 800 meters downrange. Up there at 40 feet or more off the ground, the winds are more "true" and are out of ground effect. These higher altitude winds are easily detected when you have ground that is behind the altitude of these winds. Imagine that you are on the flat of a valley at the same level as the target. There is rising ground behind the target that allows you to "see" the mirage that is 40 feet (maximum ordinate @ 1,500 meters) above the line of sight. Look at that mirage, assign a mph value to it, then determine its direction. Again, you do not correct the angle of the wind when using mirage to assess its value.

You determine the direction of the wind using mirage to get a feel for what the wind does in your target area. In the morning the wind may cross in front of you at two different angles, sometimes in the opposite direction. In the afternoon, however, because of the terrain, the wind may only blow in one direction all the way to the target.

Some of the subjects that are usually covered when discussing application of fire are not covered in this book. The engagement of snags and moving targets and methods of holdoff are not addressed as the focus of this book is anti-materiel sniping with .50 caliber guns and larger. The references to human targets in the section on point blank zero and reverse image zero are used to emphasize how well the methods work on "smaller" targets such as human ones. These methods work even better on large materiel targets unless the component for attack is small. This requires the precise range determination methods that are in Chapter 7.

FOOTNOTES

1. From TC 31-20-4 (ID), OCT. 1996 p. 3-33.
2. Quoted from Lt. Commander Art Seivers, Coach of 1969 U.S. Palma Rifle Team. Gold Medal Winning team.
3. Extracted from Naval Gunnery text, 1917 p. 409 "Air Resistance"
4. Extract from Naval Gunnery text, p. 146
5. TC 31-20-4, *Special Operations Sniper Training and Employment*, p. 3-41
6. *Sierra Reloading Manual*, 50th Anniversary Edition, p. 615
7. *Theory of the Rifle and Rifle Shooting*, *The Negative Angle Sight*, p. 122



CHAPTER 10

Field Skills for HTI Teams and Tactical Operations Training

The methods of Hard-Target Interdiction teams are not much different than the methods used by other small units. This concept is a little new though. We are introducing more than 2 men to a sniper team. With that additional number comes the possibility of having additional “heavy” guns on the ground. This gives the team depth and flexibility. It also raises the chances of a quick engagement and a quick departure for that team. Ultimately, this raises the chances of survival for that team. Team survivability has always been a problem in any of the small unit, special operations missions throughout U.S. military history. Overzealous and uninformed commanders have committed troops to operations that had small chances of success, let alone team survivability after the operation was executed.

The entire concept of Hard-Target Interdiction was intended primarily as a low profile method of a pre-emptive measures against high value target of a strategic nature. I have had lots of discussion with different personnel both inside the military and outside. One of the points that I have heard many times is, “Why not use an airstrike or a team with a Laser Target Designator to do the same thing”? There are a couple of reasons for this. The methods covered in this book are not intended solely for U.S. personnel. Indeed, anyone who reads this book that is in a military unit of another nation can put these methods to use. U.S. allies with a somewhat lower budget than what it takes to put a special operations team into a country and then fly a flight of fighter-bomber aircraft can easily have the ability to interdict threat materiel targets. The worldwide threat by terrorists to drop unguided ballistic missiles into a target is getting quite a bit of attention these days. A four man hard-target team can infiltrate a target area and engage these high threat targets with a very high chance of success and leave. That’s a truly covert operation. The nationality of the personnel and the operation are concealed. The bad guys don’t know where it came from. Consider that against an airstrike.

Another point is that air strikes generally (although not always) require air superiority, or at least some suppression of local air defense. Yes, the United States can use low profile stealth aircraft to do the same mission. Many of our allies do not have the same luxury. We may be able to conduct direct air strike mission against high threat targets in a high threat AAA/ADA environment, but at the expense of multi-million dollar aircraft? Maybe. Keep in mind that these are my own personal opinions. They do not represent ANY

policy that is in place or under consideration. Hard-Target Interdiction operations that have been considered at the unit where I worked were as a result of initiatives from within the unit. There has been within Special Operations a movement for anti-materiel interdiction for a few years now. It fluctuated on its level of importance based on the command and their interpretation of its war fighting value. Within the Special Forces units, direct action missions have always been part of the mission profile.

The words “standoff” interdiction has been used to describe missions where operators can engage materiel and personnel targets with rifle fire or missile shots. In Army Special Forces, we did a few training missions where “standoff” meant that you hung a platter charge on a fence. The idea of 12 guys (usually 8 to 10) running around on a target deep in bad guy country never really made a lot of sense to me. Seemed like too much exposure and risk. The Hard-Target Interdiction methodology was part of a plan to bring back direct action mission capabilities to SF teams because there was a strong movement within special forces to eliminate the direct action mission as part of the mission format.

This chapter is designed to do two things. As stated, hard-target sniper operations are not that different than the traditional sniper mission. The ranges may be greater and the math a bit more complex, but the ground operations pretty much are the same. Much of the rest of this chapter is similar to material that is covered in other sniper manuals. I intend to add much instructor experience to what is already out there. A lot of “on the ground” experience is written into this material. The rest of the material is specific to hard-target operations.

INDIVIDUAL NON-SNIPER SPECIFIC EQUIPMENT

Special operations sniper missions, as well as other direct action or special reconnaissance missions are always conducted behind enemy lines. These types of missions require that individual equipment be carefully considered for both value and weight on the individual. Within the different special forces groups as well as from team to team, the individual load packages vary quite a bit. This section is offered as some insight into the different methods of equipment selection and the factors that get into that selection process. Operators at times consider weight measured in ounces. Special operations missions also require planning that includes long rang unassisted evasion from enemy forces.

SF teams routinely plan on the fact that their mission will be compromised, or the exfiltration aircraft will not be able to make it to the extraction landing zone. This may require the team to move into an evasion corridor or at least wait at a pre-designated recovery point for a period of hours to days. The nature of sniper missions whether they are by conventional forces or special operations forces mean that the consequences of compromise or any other contingency are almost parallel in nature. The following is an extract from a Special Forces Operational Detachment's Field Standard Operating Procedure. The equipment list has been modified to align more accurately with the intention of the material presented here. With the exception of a heavy communications load, sniper team equipment loads are not much different than SF team operations. Keep in mind that this list is NOT intended to be an end all “this is how it must be list.” It is only an example and a guideline.

Team Equipment. The equipment to be taken on an operation will be determined in isolation. When the following items are taken, they will be distributed as indicated until the equipment is exhausted. Each team will mark his team equipment and weapons with the specified number of knots in his knotted identification cord.

Individual Combat Equipment. The following minimum individual uniform will be worn by all members of the team on alert notification and field operations. Survival kits are part of a modular system that includes three major groups of items.

- Emergency Signal items are devices to contact aircraft, boats, or other people by non-technical means.

These items include pen flares, pieces of VS-17 panel section, or even a small amount of fuel used to ignite a ground signal for overflying aircraft.

- Emergency medical items are things that you have on your person at all times and can be considered aids to evasion. SF medics usually set up pill kits that contain powerful antibiotics, antihistamines, and pain medication.
- Emergency Food Procurement. This includes miniature fishing kits, snares, materials to make traps, etc.

Uniform. The standard uniform for operations will be the lightweight BDUs. The fatigue jacket will be sterile except for rank and will have additional pockets sewn on the upper and lower (if necessary) sleeves for emergency materials. The following are minimum mission essential materials. These do not include emergency survival, medicine, and signal items.

- Watch analog or digital, no beeps and whistles.
- Penlight
- Primary compass around neck, tucked into pocket.
- Maps of area (operational, survival)
- 30 feet of parachute cord
- Camouflage stick
- Knife, combat
- Dog tags, ID card, currency
- Patrolling gloves (Nomex, Leather, etc.)
- Notebook with PENCILS.
- Tri-graph card
- Insect repellent
- Survival kit #1. The items carried in Kit #1 are the emergency medical, signal, and food procurement items listed above. These kits are carried in different parts on the team member's uniform. These items are not carried attached to the vest. They will be carried in the cargo pockets of the uniform or tied to it.

1. Pen flare gun with flares. (MSN IDENT)
2. Twelve-inch-square Minimum Panel section.
3. Signal Mirror
4. Emergency compass
5. Small folding knife.
6. Two bottles iodine tablets.
7. First Aid eye dressing kit.
8. Two aluminum collapsible cooking panels.
9. A bottle of Betadine.
10. Two packets of dehydrated soup.
11. Snake bite kit
12. Two heavy fishing line kits
13. Method of emergency fire starting
14. Evasion pill kit

- Special Equipment

1. Personal/survival weapons
2. Recovery equipment: STABO/SPIES/FULTON RECOVERY

3. Personal comfort items
4. Team special equipment, such as survival radios, beacons, etc.

Patrolling Vest. The combat vest can be individually set up to best suit that person's needs. Vests with multiple pouches are well suited for sniper/recon missions to carry all of the little things that snipers seem to packrat into their kits. The following items are recommended:

- Small arms ammunition based on backup guns
- Match ammunition for the sniper weapons systems
- Capability to carry 2 quarts of water (minimum)
- Pistol belt
- Combat vest
- 2 additional ammo pouches
- Two first aid dressing kits
- Pistol holster
- Strobe light w/ IR filter and directional sleeve
- AN/PRC-112 OR 90 if available (tied and taped to left webbing of vest, on/off switch taped over)
- Spare 9mm magazine pouch
- Butt pack (This will not be used to carry escape and evasion materials. These will be carried on uniform.) Additional items taken may be placed in the pack, no basics.
- Camouflage strips should be tied to various locations on the vest. They should be non-patterned and color neutral.

Locating equipment. Locations of special identified equipment to carry on the individual's uniform. These critical items are mission-essential or can sustain other personnel in case of the loss of a team member.

Lower left leg pocket.

1. Operational maps, WP notebook.
2. WP Crypto materials.

Lower right leg pocket.

1. Emergency food ration.

Right shoulder pocket.

1. Pen flare kit.
2. One aluminum foil square

Left shoulder pocket.

1. Panel section tied to shirt pocket.
2. One aluminum foil square

Right breast pocket.

1. Individual choice of emergency medical items
2. Individual choice of emergency signal items
3. Emergency compass (unless it is a wrist compass).

Left breast pocket.

1. Currency as needed.
2. ID card
3. Penlight tied to shirt.

Lower left shirt cargo pocket.

1. Signal mirror, taped and padded.
2. Lighter or WP matches.

Lower right shirt cargo pocket. This place is for any additional items not covered specifically identified above. The above items are not the only items in those locations. These are minimum items, however.

Rucksack. The following minimum additional items will be stored in the individual rucksack and be maintained in a constant state of readiness.

- Two waterproof bags
- Poncho liner
- Extra compass in center top small pocket.
- Lightweight Gortex suit
- Two 2-quart canteens—covers optional
- Two MREs
- Two ponchos
- E-Tool with carrier
- Extra rucksack straps in bottom of ruck
- Sniper veil w/ black balaclava
- Ruck net
- Three drive on rags
- M16 cleaning kit
- Half a roll 100 mph tape
- 1 liter Ringer's IV located in top flap of ruck.
- Two IV infiltration kits w/16 gauge needles
- The following will be packed in a rucksack side pouch: Film magazines for X 4 rolls film, Survival Kit #2 and four tripwire kits.
- Air items.
- 50 feet of parachute cord
- Sewing kit
- Survival and Evasion Kit #2
 1. Signal Mirror
 2. Aspirin
 3. Chocolate bar
 4. Ten bandages
 5. One bottle of Betadine
 6. Ten safety pins
 7. A book of matches and a lighter
 8. A roll of medical tape
 9. Medical thermometer
 10. Six yards of 2-inch wide gauze
 11. Two tubes of ophthalmic ointment
 12. Two pill bottles
 13. Two cravats
 14. Steri strips as recommended by Medic
 15. Sutures as recommended by Medic
 16. Extra Betadine as needed or determined
 17. Four rolls of tripwire

A visit to various sniper web sites has generated the lists of equipment on these pages. These items are based on about seven different operational detachments' experience on what they used and the author's old team operating procedures. Some variation was allowed of course, but the listed items are mandatory. Many operators added to these items based on the specific mission needs.

THE ART OF CAMOUFLAGE

The principles of camouflage have not changed much during the last few wars. It is considered one of the top priority field skills that lead to mission success or failure, and the team living or dying. Camouflage discipline begins with pre-mission planning as the operators examine the flora and fauna of the target area in their area of operations. Is the area a desert region or is it heavy jungle? Is there continuous vegetation coverage, or is it spotty, requiring the team to cross vast open areas where observation by fixed surveillance is likely?

Most of the military sniper publications concentrate on the camouflage of the sniper team in and around their final firing position. There is little emphasis on the movement phase or on the overall mission application of camouflage. This is left up to the unit's procedures on the training of that individual soldier outside of sniper operations. Throughout U.S. military history, different camouflage uniforms were used with varying degrees of success. U.S. Special Forces have had different camouflage uniforms available and issued during most of their history. These uniforms were usually tailored for the conflict of the times. The tiger stripes were designed for use in Vietnam and the rest of the SE theatre, and were quite successful. The standard issue uniform for the time, the OG-107 jungle fatigue, became the standard uniform for Army special operations soldiers in the early and mid 1980s. The Battle Dress Uniform (BDU) came out and was pretty much forced into use against the will of the ground operators in both the Ranger Battalions and the Special Forces Groups.

The OG-107s were frequently dabbed with paint by SF soldiers to help with the camouflage for their area of operations. These splotch patterns were quite effective as a neutral base for attaching camouflage as needed once on the ground. While this method is not always very effective, at least the effort was being made to additionally camouflage the uniform. In 1981, the new Battle Dress Uniform hit the clothing sales stores in Europe. The author was in a conventional Army unit at the time. The field uniform for the conventional army in Europe was the olive drab field trousers with the wool shirt and a field jacket for additional warmth. The ONLY camouflaged item was the helmet cover. Sometimes the Army is slow to react to change.

When the BDU was released, it took a few months for commanders to actually authorize it for wear in the field without wearing the old non-camouflaged field trousers and wool shirt over the top of the BDU. Didn't make much sense. All of the unit sergeants major were waiting for "guidance" on the wear of the uniform. The field troops all figured the pants and jacket went on the same way as the old uniform, with the exception of not tucking the BDU jacket into the trousers. However, I do remember a couple of discussions in our platoon room about the commander's considering having the troops tuck in their jackets while in garrison. The wonders of the conventional army never ceased to amaze me. Those strange thoughts were not limited to the regular army however as the late '80s and early '90s proved within the Special Forces groups.

SF units wore the OG-107 as a garrison and field duty uniform well into the '80s. The BDU uniform was beginning to make its way into the minds of sergeants major as they were beginning to force the ODAs to wear the BDU in garrison as well as in the field to replace the OG-107. The BDUs wore out faster and although they had a camouflage pattern, the pattern was LESS effective in SE Asia than were the old non-pattern OG-107s. Even now, operators long for the older OG-107s, at least those that were around in the days of that uniform.

What is the major problem of the BDU? Well the uniform was designed for a certain climate. That would be the European Theater. It also worked well for certain posts in the United States. It was and is totally worthless in any of the Asian area of operations. The uniform is more effective as it fades, but that brings up another problem. About the time the uniform begins to fade, the unit sergeants major want you to exchange them for "newer" looking uniforms.

The biggest problem with BDUs is the presence of a non-natural color. Black is a color that does not occur in nature. I know this will raise some eyebrows, but the color that appears to be black are many shades of blue and gray. The uniform would be fine without the black and if the other colors were less busy. German camouflage suits of World War II were quite effective and the patterns were blotchy and less busy.

The color black in a uniform also creates another problem. Do you ever remember wearing a black shirt or pants on a day when the sun is out? If it's warm, that shirt or pants probably got uncomfortably warm or it warmed up to be quite comfortable. Black absorbs heat. When observed through night vision devices or, worse yet, a thermal imager, the color black stands out like a turned-on light bulb. Black reflects infrared light, which the NVDs detect. An individual wearing BDUs may not stand out much against the background, but those black spots are like little "reflectors" all over the uniform. The point is that black should be totally avoided as a camouflage color. Many urban units use black in their uniforms. The elite military units will refer to the psychological aspects of this color. That is a valid point. Black in an urban environment is as bad a color choice as it is for desert or jungle operations.

Before we get into the aspects of camouflage, let's look at the reasons why an individual or piece of equipment is seen by the eye. These "Target Indicators" are things that an individual does or does NOT do and this results in his detection by an enemy force. Target Indicators are also things that the friendly force sniper uses to detect the presence of enemy personnel. These factors are grouped into four major areas. They are olfactory, tactile, auditory and visual factors. These factors do not just apply to snipers and sniper operations. They are part of the overall camouflage game.

Olfactory Indicators

Olfactory indicators are things that the enemy can "smell" about friendly forces. This encompasses a lot of information. For major units in the field, these smells include cooking fires, field latrines, exhaust smells, smells of solvents and other smells. For the small unit in movement, the smells are about the same: smells from a cathole, clean uniform, a body that is too clean, weapons oil and other sources. To an enemy soldier in the field, those small odors stand out like a roaring bonfire. In SE Asia, interviewed POWs often said that they could smell the presence of U.S. forces. One reason they could smell the particular body odor of U.S. forces was because of their diet. The huge contrast in diet between U.S. food and the indigenous food resulted in a different body odor that enemy forces could easily detect, although initially it was probably by accident.

Special operators that are going to operate in areas where enemy forces may be sensitive to olfactory indicators should take special precautions long in advance of moving through the enemy area. Some of these precautions include:

- Switching to a diet of indigenous food 2-3 weeks before the operation if possible. This period may not be feasible or the food may not be available. In that case, eat a more bland diet. Avoid spicing the foods completely. Avoid red meat and eat fish or chicken. Increase the intake of roughage as a cleansing process of the body's digestive system. Drink more water not only to pre-hydrate, but to additionally clean the pores and digestive tract. Avoid the high-energy drinks as they leave a particularly strong odor when sweated out.
- Do not use soap for bathing 2-3 days before the operation. A good hot water rinse opens the pores of the skin and does a sufficient job of cleansing without adding the odor of soap to the body. This soapy odor is intensified when combined with the sweat process.
- Insect repellents have long been a source of olfactory indicators. The new cream in use by the military is a great improvement over the old style. The Avon product Skin So Soft is said to have excellent mosquito repellent qualities but gives off a strong but pleasant odor. Definitely not recommended.
- Lysol disinfectant initially gives off a strong odor but over the period of a couple of days goes away. It can be used initially to suppress odors coming off gear then allowing the odor of Lysol to dissipate for 48 hours.

When washing field equipment, use a mild dish washing soap. These odors are weaker than most cleaners are, and when air-dried for 24 hours, the odor dissipates to nothing. The bright warm sun does a lot to deodorize items dried in the air. Avoid using fabric softeners as these leave a long lasting odor on items washed in it.

Here are some aspects of detection that the friendly force sniper can use to detect enemy presence. All of the above factors are things that we can use to detect the presence of enemy personnel. The diet of the adversary can be used to a great advantage when you have cleansed yourself using the mentioned process. Have you ever noticed how you don't seem to smell too bad after an operation until you get around other clean people? Then suddenly you notice your own bad stink. Vietnamese use spices in their diet that results in the body odor being particularly pungent. The same is true for Koreans.

- You must tie in wind patterns and the terrain to take advantage of your sense of smell to detect enemy presence. Be aware of the direction of the wind and be downwind when possible, from natural lines of drift or trails that enemy forces may take.
- Enemy positions give themselves away based on smell for the same reasons that we do. Smelling for cooking fires, smoke, weapons solvents, or exhaust will give away enemy positions. Again, you must use the wind to determine the direction of these forces. Suspected enemy locations should be flanked so that you are downwind from them as you pass by. This may either confirm or deny their presence. It will also carry away any odors you may have away from their detection. This is a good counter-dog measure to keep in mind.
- Avoid locations of firefights that may have taken place. Be aware of the smell from fired rifles and the odor residue from explosives, grenades or mortar fire. Depending on the enemy encountered, they may return to look for missing personnel, look to pick up a POW, or do a damage assessment of the area. Bottom line is if you can smell gunpowder or burned explosives, back up, go around by a long ways, and get very alert.

Tactile Indicators

Tactile indicators are things that can be touched by the enemy. They are used to verify the existence of friendly snipers in the area. This means anything from trash being left behind to pieces of material that fall off the uniform and equipment. A much-disciplined process of eliminating the possibility of equipment falling off or losing things is necessary. Units that spend a lot of time in the field have engaged in the art of "dummy cording" easily lost pieces of equipment to themselves. This is usually done to prevent the loss of valuable pieces of equipment. There is a more serious reason for not losing stuff when deep in bad-guy country. Just think of the reaction by an enemy force commander at finding a round of match ammunition. The M118 round has a little cross on the base of the brass. The brass is not the same as 7.62mm brass from the M-80 Ball round. The new round called the M118Long Range round uses match components across the board. This adds a whole new level of concern about leaving a piece of brass lying on the ground. The same goes for special .50-caliber rounds of ammunition. The .50-caliber machine gun is in many places in the world. For an enemy to find a pile of this brass with links at a previous battle site may mean nothing to him. To find just one piece of brass from a .50-caliber rifle with no link scratches may set off some serious alarms to a sophisticated analyst. Here are some preventative measures against leaving tactile indicators.

- Sniper ghillie suits are a notorious source of tactile indicators. Bits of garnish, camouflage net, canvas and anything else that is used to break up the outline on the suit easily becomes dislodged during use. When attaching this garnish to the suit, don't be content with simply gluing it in place. This may work in a school environment where you are not evaluated on indicators left behind. In the operational world, these indicators may bring the bad guys. Snipers must constantly check their back trail to make sure that bits of ghillie suit are not left behind. Long upright movements into a target area with the suit on are bound to leave evidence of passage.
- The use of burlap garnish on field gear is a good one for camouflage but frequently leaves evidence of passage. Usually this type of camouflage doesn't receive the care and maintenance that it takes to keep the residue from hitting the ground during movement. The tail gunner's job is to ensure that "sign" is not left

behind as a team passes. That's a tough job when you are also doing tail watch and eradicating physical sign of a team's passage.

- Carefully go through all of your equipment and make sure there are no loose snaps, buckles, or eyelets. Canteen caps should be dummy corded or otherwise secured so they don't vibrate loose and fall out. On vest assemblies that have metal snap hooks, these should be taped to reduce noise as well as prevent failure and subsequent loss.
- All pockets that are external should be double stitched to keep heavier items from ripping out the stitching and falling out. Normal BDU and field uniforms have reinforced corners only. Never replace buttons with Velcro for field uniforms. In fact, all forms of Velcro attachments should be removed and replaced with buttons. Buttons are easily repaired in the field and don't come loose when they get wet as Velcro does. Back pockets are especially notorious for coming open on BDUs. Avoid using the back and the front hip pockets to carry items at all, since they cannot be closed and sealed.
- Any sniper specific items that are easily misplaced should be carried in a bag that has a good zipper seal and a storm flap to keep those items from accidentally falling out. Ideally, these are tied shut over a zipper.
- U.S. forces are required to carry their ID cards at all times. The same holds true for ID tags. Most team members reinforced their tag chain with a sheath of 550 cord. This also kept the chain from abrading the neck on long patrols. The ID card can be inserted in a special sleeve and then this is attached to the reinforced chain around the neck.

Tactile indicators detrimental to enemy forces are things that a point man would normally watch for while doing that job. This evidence may indicate that an enemy patrol has moved through the area, or it may indicate the presence of an ambush. Items include trip wires (goes without explanation), presence of field telephone wires, trash residue, field latrines, stained leaves and grass from urination, careful clearing of fields of fire, or the careful removal of a shrub or tree branch to clear fields of vision for surveillance and observation.

Auditory Indicators

This is a very wide-ranging subject that covers everything that is done from infiltration through movement and up to and including the sniper shot on target. Auditory indicators are tied to olfactory indicators in that they are channeled and enhanced by certain wind conditions and aspects of the terrain. Weather conditions, time of day (or night), air temperature, and even level of alertness of the snipers all dictate the range at which auditory indicators mark their presence to the enemy.

- Tape anything that can rattle with OD duct tape (100-mph tape). Directly tied in with tactile indicators and loss, remove any metal attaching devices and replace with a soft loop system using tubular nylon. Hand stitch it if necessary. This also cuts down on weight and is more durable in the long run. Removal of as much metals as possible on harnesses and rucksacks cuts down on noise problems.
- Pills that are carried in bottles are notorious for causing noise when moving. Carry pills in plastic bags and if you must, then insert this into the plastic pill bottle for durability. Make it silent, then make it durable.
- Military belt buckles are the source of many a noise during movement. Use an A7A strap—it is stronger, has many uses, and doesn't come loose and rattle constantly.
- Finally, when you are ready for movement lay out all your individual gear and check it out. Pick up the rucksack and shake it, slap it, bang on it with a tent peg, try to MAKE it make noise. Turn it upside down and shake it. Do this with all of your equipment. Wring out every source of noise that you can. Suspect all metal objects of being able to migrate in your rucksack to other metal objects. Together they make noise. This is inevitable, so ensure that they can't migrate by separating them and padding them.

Because sniper operations are frequently carried out in the enemy rear areas, the use of auditory

indicators to detect enemy forces is a major plus to the sniper teams. The same indicators that are listed under olfactory for detection of enemy units apply to auditory indicators. The farther away from front lines or battle areas the enemy units are located the more likely their noise discipline will diminish. This is true for all armies except for the most disciplined guerrilla units.

- The size and sophistication of enemy forces many times will tell you the amount of noise level you can expect to encounter to help locate those enemy forces. Small guerrilla bands are going to be much more difficult to detect. They may have a lower discipline level, but that's a dangerous edge to count on. The sounds of weapons maintenance, the clanking of the metal parts carries a long way in all conditions. You will hear these sounds during the day because you have to be able to see to clean that gun.
- Larger units will have the tell-tale signs of big unit operations. Generators, vehicles starting up, orders being shouted, and the crackle of radios all add to the racket caused by large units in the field. Frequently the auditory indicators are the first signs that are detected that an enemy force is in the area.
- When these sounds are encountered during the sniper team's movement, they need to carefully consider the conditions to determine the enemy's location. Perform a listening/security halt and look at the wind conditions. Examine the map and compare the winds to the terrain that is surrounding you. Just because you "heard" the noises from in front of you doesn't mean that the enemy unit is located in front of you. The winds and terrain will move those sounds around and can be very misleading as to the true location of that enemy force.

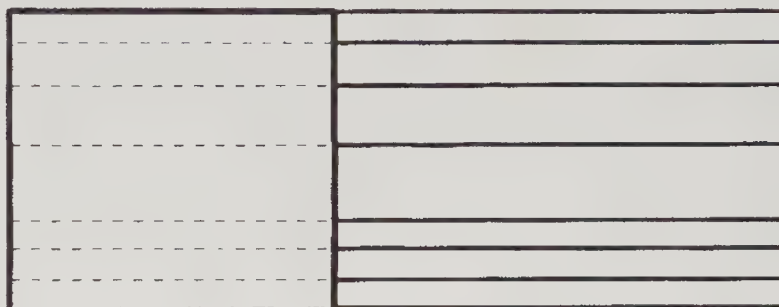
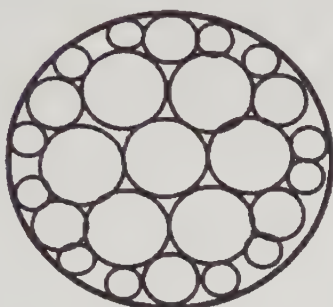
Visual Indicators

Visual indicators are things that enemy forces see about the sniper or sniper team. These indicators are present when the team is under direct observation. Clearly, the most dangerous aspect of detection to enemy observation is a visual indicator. Detection of friendly forces through olfactory, tactile and auditory measures are more long-range detection aspects. This gets the enemy's attention and may bring on trackers or at least increase the readiness levels of units in the area. Though you may be detected at long range by the other three factors, this does not mean that you have to get "fixed" by the enemy in the area. The only thing left that will give you away and bring about your destruction is being detected by visual indicators.

- Movement. The human eye is naturally attracted to movement. During a stalking exercise, the instructor almost always is attracted to a student's efforts by locking in on his movement. After seeing the movement, he uses other visual indicators to lock down the location of that sniper student. Jerky and twitchy movement always attracts attention. A small unit on a patrol can usually slip through an area under casual observation if their motion is slow and fluid. As the team members move along, hand signals, alert signals, arm and leg movement, turning the body, moving the weapon around, etc. all must be done with fluidity and slow movement. A point man suddenly freezing and sticking his arm up next to his ear with the "freeze" signal is highly likely to get visually "fixed" as a result of this jerky motion. A nice slow stop followed by a freeze signal given at the lowest height necessary to transmit to the rest of the team is much better. Most SF teams' SOP states that hand and arm signals are given at waist height when possible.
- Improper Camouflage. Improper camouflage ranges from a bad combination of colors and poor texturing of the camouflage materials to good camouflage that has worn off or has died off enough to be detrimental. Camouflage must be constantly updated and modified to the area that you are operating in or moving through. The use of natural camouflage is always recommended but requires a higher level of camouflage discipline. Constantly changing and updating natural camouflage requires severe discipline that few can maintain for more than a couple of days of strenuous movement.
- Shine and Reflection. Metal objects are the greatest points of consideration in relation to shine. The finish on the barrels of the earlier M-24s was called Remcoat. The finish on the earlier guns came off

easily and left exposed stainless steel. Operators were forced to paint over the exposed metal to enforce camouflage discipline. The earlier finish, while not only a bad color (black) also had a pretty slick and shiny surface texture. The finish was glossy black of all things. Night, urban operations even required extra special treatment because of this glossy finish. The lenses of the optical sights and spotting scopes cause particular reflection problems. The sunlight diffuser below is a method of breaking down the blackhole problem of the end of the scope. It also eliminates the problems of sun reflection against the objective lens of the telescopic sight. Paint the inside of the tubes heavily with a flat matte light green or tan color. Use the sunshade issued with the day scope or fabricate one out of a plastic tube and tape around the end of the day scope.

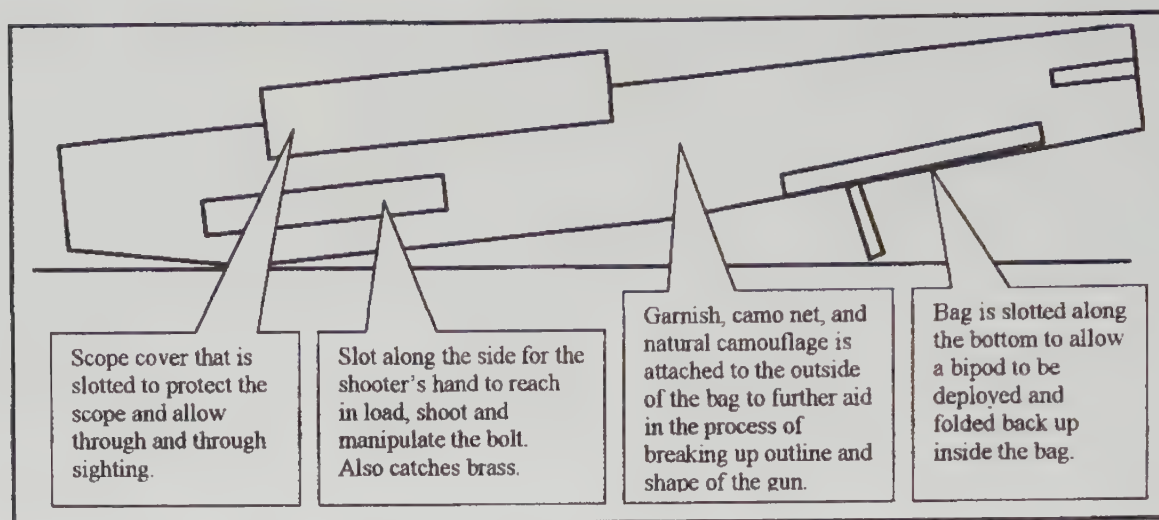
SUNSHADE IS PACKED WITH 1/2" AND 3/8" CLEAR PLASTIC TUBING THAT IS ABOUT 6" LONG
LARGER DIAMETER TUBES ARE IN THE CENTER OF THE SHADE. PAINT THE INSIDE OF THE
TUBING WITH A LIGHTER GREEN OR GREY.



LIGHT ENTERING THE FRONT OF THE TUBES WILL BE REFLECTED AROUND INSIDE OF THE
TUBES AND TAKE AWAY THE "BLACKHOLE" EFFECT WITH LIGHT DIFFUSION

- **Outline and Silhouette.** The outline and silhouette of the sniper are the two things that camouflage are intended to defeat. During all phases of the operation from infiltration to shooting at targets the day to day camouflage are designed to defeat these two visual indicators. The ghillie suit alone is not enough to keep enemy observers from detecting the presence of snipers in the area. Camouflaging the rifle and associated sniper equipment to break up the outline and silhouette must not contrast with other camouflage methods used. A ghillie suit is intended to not only blend with the surrounding area, but it totally breaks up the outline by presenting a bulky non-linear appearance. Many times the sniper's camouflage of the rifle and spotting scope is contrary to the method of the ghillie suit. For this reason, a "shooting bag" was designed to camouflage the rifle. The shooting bag is a different concept than the drag bag. A drag bag is used to move the rifle without allowing damage to the gun. However, the drag bag as defined in TC 31-20-4 *Special Operations Sniper Training and Employment* and TC 23-14 *Sniper Training and Employment* do not allow the rifle to be operated and fired from inside the bag. The weapon is non-usable for offensive and defensive operations to the sniper carrying it.

With a good understanding of the reasons why the enemy and we are seen, it is easier to plan the camouflage of your person and your equipment. When you plan your camouflage, think as if you are the enemy that is going to look for you. Assume that you are going to pass under direct observation. With that in mind, remember that detection means destruction. Severe camouflage discipline is paramount to mission success and just as important to survival for the operator on the ground. For the sniper—without sufficient



defensive firepower, many times beyond the range of indirect fire support and without air support—hiding from the enemy is the only chance of escape after the shot is taken.

The Fundamentals of Camouflage

The fundamentals are the aspects of camouflage that are guidelines. These are general procedures to follow when camouflaging the three major subject areas for operations. These three subject areas are:

Individual Camouflage

These are the uniform, personal equipment, and exposed skin camouflage that is applied for all phases of the operation. The patrolling harness or vest, headgear, boots and the weapon (whether it's the sniper rifle or another weapon that the sniper moves with). You must remember to check your camouflage plan against the factors of why we (snipers) are seen and why we see the bad guy. If your plan doesn't stand up to the scrutiny of direct observation while sitting still, it won't have a chance when being observed while in movement.

In combination with the methods of natural and artificial applied camouflage snipers, use temporary *hiding* methods to stay concealed from enemy detection. Hiding methods by their nature tend to defeat olfactory and auditory target indicators. Security halts during infiltration and movements are taken at points where the densest vegetation available can be taken advantage of. The team moves into this dense vegetation and uses that as a form of movement security. Enemy soldiers on patrol will seldom penetrate dense vegetation unless there is no other way through, they suspect the presence of enemy forces in their area, or they are part of a larger random search pattern.

Blending camouflage methods are those that are designed to specifically defeat visual target indicators. The snipers try to blend into their background by employing skillful use of natural and artificial camouflage. Natural camouflage means are the easiest to change in movement. Care must be taken though not to leave visual sign of the operator's removal of natural camouflage materials. Blending techniques tie in very heavily to the principles of concealment.

The practice of *disguising* is used to try and trick the enemy into thinking that the sniper team is doing something other than it is really doing. Carefully use deception measures as the use of these can actually alert enemy forces to your presence when they may NOT have noticed your presence before. Generally, disguising and deception measures are used behind enemy lines only when the sniper teams suspect they are compromised. These deception measures come in the form of active and passive measures.

- Passive measures include some things that tie directly into passive counter-tracking (CT) measures. A team that moves snake-like through the woods and does not break twigs or branches and takes great care not to compress leaf and ant piles are employing passive disguising (counter-tracking) measures. The author has used a 6-foot-long piece of burlap to lay across trails that are easily damaged by troops crossing as a CT measure. The point man lays down the burlap and everyone steps across slowly and carefully, trying not to damage the soil under the burlap. The tailgunner picks up the cloth as he passes by and checks for any evidence left behind of the team's passage.
- Active Measures. When a sniper team is moving in an area and they suspect they may be under direct observation and possibly compromised they should take active counter measures. These include procedures to disguise both their unit's composition, disposition and strengths as well as their intended mission. More of these active counter-measures are covered in the countertracking section. The biggest problem is detecting the possibility of compromise and then implementing the procedures. The more serious countermeasures include methods of luring out enemy personnel so they can be engaged and allow the team to escape. Clearly this means mission compromise and failure.

Sniper Specific Personal and Equipment Camouflage

Sniper specific camouflage pertains to the special camouflage procedures and guidelines for camouflaging the sniper rifle, special observation optics, range finders, and anything else that could come under direct observation during the execution phase of the sniper mission. These items deserve special consideration because of the possibility of countersniper elements watching with high-powered optics. Super detail is needed to defeat observation by high-powered optics, but that is as much of a game against the adversary as it is camouflage.

The procedures that are specific to sniper weapons and equipment are the things that apply mostly during a stalk (not a likely occurrence) or the camouflage of things while in the Final Firing Position. One of the most common mistakes for a sniper student is to try to blend into the base of a tree or a bush. The big black hole at the front end of the scope is difficult (but not impossible) to conceal. If a shooter backs deeper into the shadows, those black spots that are lacking camouflage or deception methods will blend much better.

Hide Site Camouflage Principles

Hide site camouflage pertains to defeating enemy detection of the hide site for 360 degrees around the site. Typically, the side toward the target area gets special emphasis. Clearly, that is an important fan of coverage. It is the area behind the site, where the snipers approach from that may prove to be the most dangerous for the snipers in the hide site. Hide sites have to be very carefully sited to support the type of camouflage that is needed to conceal the presence of the site. The type of construction will also depend on the location of the hide. For example, a hide site in the hilly countryside of Korea may require a hide that can support human weight. There are very limited fields of vision and fields of fire. Locating a hide site off a pathway probably will require that the hide site be dug into a hillside with a 60 percent grade or worse. It is possible to set in a hide on a trail, but it absolutely must support human weight on its roof. Details of hide site camouflage are covered in that section of this chapter.

The Principles of Concealment

These principles are tied to proper camouflage techniques. Used in combination, the camouflage techniques and the principles of concealment are a formidable prevention to detection by enemy forces. Many times, the camouflage looks good, but it only looks good. It doesn't have to look good to be effective if it follows the principles of concealment. Ignore the principles and the reasons why things are seen and the "best looking" camouflage will fail miserably. Remember, however, that everything that can conceal can also get you compromised when used incorrectly or without careful consideration.

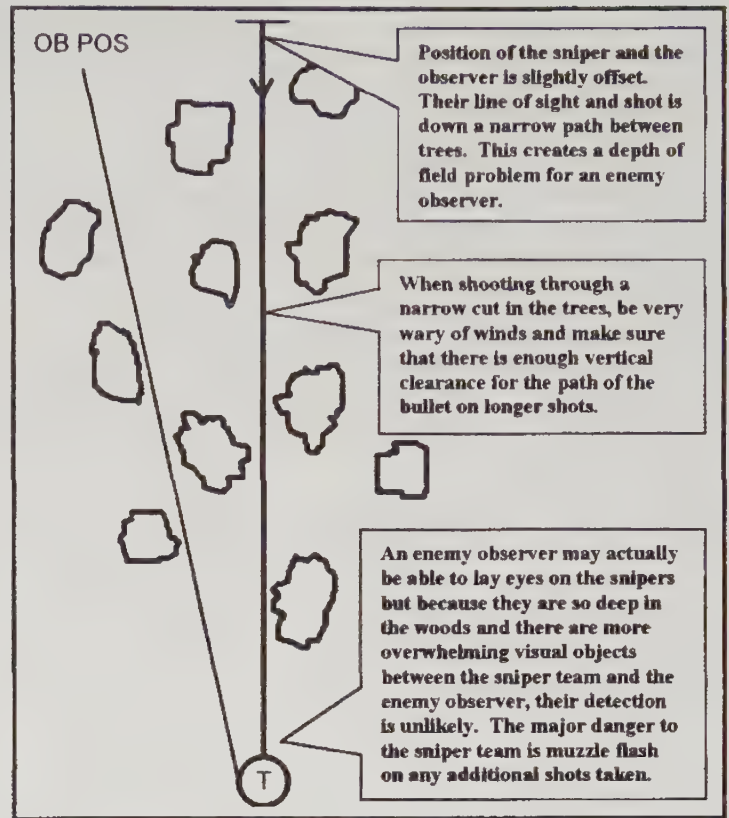
- Shape. Soldiers of all armies and their equipment have specific shapes that other soldiers readily

recognize. These shapes that, when observed, cause alarm to the enemy are a visual target indicator. These easily recognized shapes must be disguised and broken up. Good examples are the barrel of a rifle or the antenna on a radio.

- **Shadows.** When used correctly shadows are a great method of concealment for snipers. The biggest reason that shadows cause problems though is that a person will sit too close to the front end of the shadow. When using shadows to conceal, move as deep as possible into the shadow. This causes a depth of field problem for a person trying to see what is in the shadow. Shadows are also a major source of problems for snipers stalking out in the open field. When snipers do the dreaded “ground hog” maneuver and pop up to look around, the shadow follows them up. Busted.
- **Silhouettes.** The silhouette of an object on the battlefield is tied with the other principle of shape. The old GI steel helmet is a classic example. The new classic example is the kevlar helmet of U.S. issue. Some units in the U.S. Army have gone to great lengths to break up this outline. They have attached strips of BDU material to break up the outline of this helmet. At times, great ridicule has been heaped on those soldiers as “rag heads” and such. Their effort is a good one and effectively breaks up the outline of the K-pot. Additional garnish or strips of material attached to the combat harness of the uniform helps break up the silhouette. Pieces that fall off, however, are great tactile and visual target indicators for enemy forces.
- **Surface.** The surface of an object is a major part of successful camouflage. This is mostly referring to the texture of that surface. As mentioned earlier, the shiny barrel of the older M-24 rifles violates the principles of shape, silhouette, surface and color in its issued state. Texture is the major component of the surface principle. An object may be painted to blend perfectly. If the background and objects close to the object being camouflaged are of a very coarse texture, the camouflage may not pass close scrutiny under direct observation.
- **Spacing.** This is a tricky factor. For moving objects, such as a small unit on a patrol, spacing means a couple of things. Spacing on a moving patrol provides a degree of protection against total wipeout by concentrated small arms fire or a tossed hand grenade. As far as a concealment principle, good spacing means that an enemy observer may not see a single blink of movement from one sniper. However, if the other one is too close by, the enemy observer is sure to see him. If the spacing is such that many seconds will pass from the first to the second sniper’s movement through observation, the enemy observer may move onto another area before the second sniper moves into his field of observation. For the friendly sniper, moving through a field of observation his path should take one slightly different from that of his partner. By doing this, he may place a visual obstruction between himself and the enemy observer. He would not have any idea this occurred, but such weaving and bobbing may save their life. When more than one sniper team is used on a operation, spacing means having them far enough apart that hide sites do not over clutter an area. It also keeps the teams from stripping off too much natural camouflage from one area.
- **Color.** This is the first principle that comes to the mind of most people. That’s why camouflage paint was developed. Blend with the colors of the background. It is important to remember that NONE of these principles stand alone very well without applying the other principles in the camouflage plan. Colors that do not match contrast enough to catch the eye nearly as fast as motion. Next to movement, color and texture are the biggest reason that sniper students get nailed on stalks. Disciplined camouflage methods require frequent halts to update and modify the natural or man made camouflage on the sniper. This applies as much to the patrolling phase as it does to the shooting phase of the mission. You have to stay hidden to get to the target area and you want to survive the job.
- **Movement.** The eye is naturally drawn to movement. When you are lazily watching an open area with little natural motion, the slightest movement will attract your eyeball to that spot. During daylight and at nighttime with Generation III night vision optics or better, rapid and jerky movement is likely to be spotted. Sniper teams and other small units (up to 8 or so) can use very slow motion combined with

bobbing and weaving movement patterns and good spacing to offset the chances of visual detection by an enemy fixed observer. A highly trained fixed position observer can make a sketch of the area. He considers the daylight conditions and he may use this sketch to determine if something is moving through the area. The location of an object is his area of view may move so slowly that he cannot see its motion. However, by comparing newer conditions with his sketch he may detect an anomaly that reveals the movement of an individual through his field of view.

- **Siting.** Siting is a factor that more applies to stationary positions than it does to the member of a patrol for example. A sniper team taking a shot from a woodline can use siting as an optical problem for an enemy observer trying to detect them. Siting is also a concealment factor when laying in a hide site or multiple hide sites. Essentially, siting is considering the terrain, mission, and dispersion of forces to aid in the concealment of the sniper team. Here are some examples of snipers using siting as a concealment aid.



1. A sniper team is set up deep in the woods to take a shot at a target in a valley to their front. As they sited their position in, they started at the edge of the treeline and started moving back checking line of sight and shot. The shooter finds a line to the target that narrowly clears trees to the left and right of the path of the bullet. What this does is create depth perception problems for an enemy observer. As he is looking into the treeline for a sniper, the trees that are in front of the sniper to the left and right of the line of shot make it very difficult for the enemy observer to spot that shooter. The friendly observer is set up as close as possible to the gun but not in the same line of sight through those trees. He may be set up in his own optical illusion problem for the enemy observer. This may make it more difficult to read the trace of the shot, but that is something for the sniper team to evaluate on the spot.
2. The siting of hide sites is very important to their survival. A hide site may blend perfectly with the local area. The loop holes for shooting through may be perfectly disguised against any visual observation by the enemy. Everything could be perfect, but if the hide is sited badly, that place will stand out like a sore thumb. Another consideration in siting a hide is when a countersniper effort is operating in the area. To defeat a good countersniper effort takes some very time-consuming and at times ingenious procedures to defeat their own countermeasures. Siting the hide site can take advantage of terrain to aid in the masking of the hide site.

Analysis Site 1. This position follows the rule of being on the high ground overlooking the entire area. It is likely to be easily spotted because of silhouetting, shadow, and siting problems. There is no masking from

terrain features and avenues of approach and escape are not concealable nor useable.

Analysis Site 2. Site 2 is a little better than Site 1 because the line of shot is across the face of the hill and the ground does not abruptly drop away in front of Site 2 between it and the target area. It is located on high ground and has the cut behind it for the snipers to bust out into if they have to. It is a better defensively located site than all the rest.

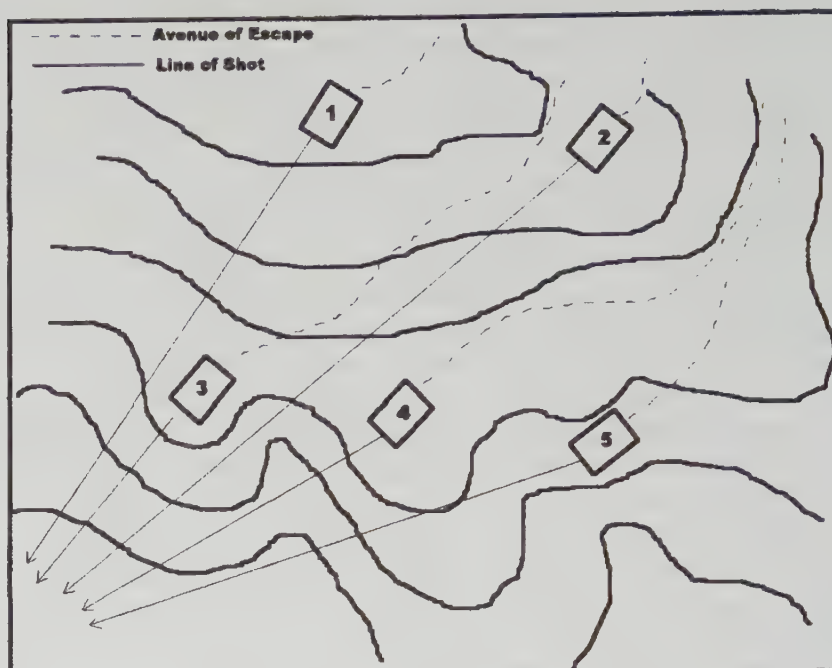
Analysis Site 3. This site is almost in the same predicament as Site 1. Escape for shooters at Site 3 is difficult because they will have to depart going up and away from the target area. Site 1 has better escape avenues. Site 3 is closer to the target

but that is dangerous for the very reason of close proximity and bad avenues of escape.

Analysis Site 4. Site 4 provides a good field of fire to the target, has a reasonable escape route by following the contour line in the direction of Site 2. Enemy forces approaching Site 4 will have to either cross the cut to their front, approach up the ridgeline to the team's left, or try to follow the contour line around to the right front of the team. The team's line of shot from Site 4 will cross another piece of high ground to their front. This causes a depth of field problem for enemy observers. By putting Site 4 on the military crest of this ridgeline, the enemy observer will also be looking uphill into brighter light making his job more difficult.

Analysis Site 5. This site allows a slightly better attack line than does Site 4. They are not only shooting over a rise in the ground but the ground rises up sharply to the left from the enemy's point of view. The same situation for enemy approach applies to Site 5 as it does for Site 4. Avenues of escape are slightly worse for Site 5, though.

Siting can be the determining factor if a hide site is compromised or not. As stated earlier, all other factors could be followed and in place. Put the position in a bad spot and you're doomed. Additional methods of defeating countersniper operators are discussed in the section on hide sites.



GHILLIE SUITS

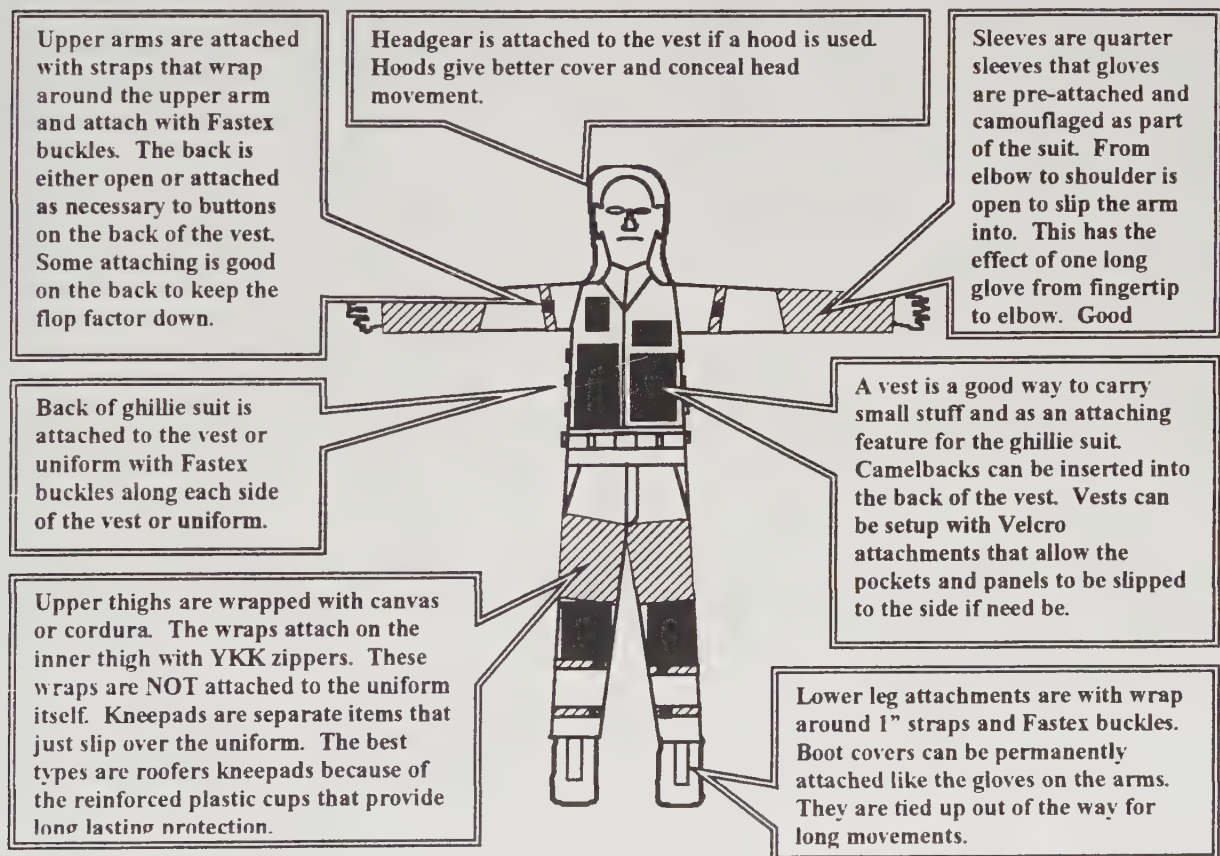
Ghillie suits have for years been the major method of camouflaging the individual sniper. That fine tradition will probably go on for years and years. They are effective and they are also big, bulky, hot, and probably overdone for real-world operations. For years snipers have developed ghillie suits as they built them for a schoolhouse environment. In the school, snipers stalk over and over. Different schools have a different methodology on scoring the stalk, but in the end, all stalks are destructive to these suits. Ghillie suits that are built for the long haul take many hours.

The traditional ghillie suit in U.S. methodology is built for repeated use over many many stalks. Skid pads are attached by using shoe goo, thread, and a combination of the two. These pads are made out of canvas or, when the operator can find it, cordura nylon with a padding material under it. In a school environment, this is designed to keep the suit from falling apart before the end of the course. Headgear is either a modified jungle hat or an oversized hood that is attached to the jacket. Hoods are good because the sniper can turn his head without the hood moving and possibly giving him away.

Traditional ghillie suits have pockets sewn inside of them for different pieces of sniper kit. The leg trouser cargo pockets sometimes are retained to carry additional items in also. Camelback water containers are worn under the jacket, or they have been carried tied to the inner legs to keep the profile down. The sleeves have loops sewn into them to keep the sleeves from riding up the arms while moving.

Boots are either selected to match the terrain as much as possible or painted to match the terrain. Sandbags can be cut and lashed around the book. This is quite effective at breaking up the outline and cuts down on trail sign while walking. Remember the tactile and visual target indicators when developing the suit. Traditional suits work well but have severe operational limitations.

The traditional ghillie suit offers excellent protection against visual detection. Because of its design it is a hot and bulky suit. You must also carry the suit separate of your field uniform. Rolled up as tight as possible, these suits are still about 18-inches by 12-inches wide. Some are smaller—it depends on the density of the suit construction. There is another type of ghillie suit that individuals have developed differing themes on. This is the attaching ghillie suit. It is part of a modular system that has the suit attached to the vest and other parts of the uniform and body with a system of straps and buckles.



These attaching ghillie suits are not as bulky as the traditional suits. They do not require stripping down to skin to put them on. Traditional ghillie suits take up to 30 minutes to put on and tailor with natural camouflage. The attaching suit takes about 3 minutes to put on and another 10 minutes or so to tailor with natural camouflage for the area. These suits are much easier to move longer distances under more severe climatic conditions. Ventilation is at a premium with ghillie suits and the attaching type is mostly open in the front. The traditional suit method of attaching skid pads to the front is ignored with the attaching suit. This

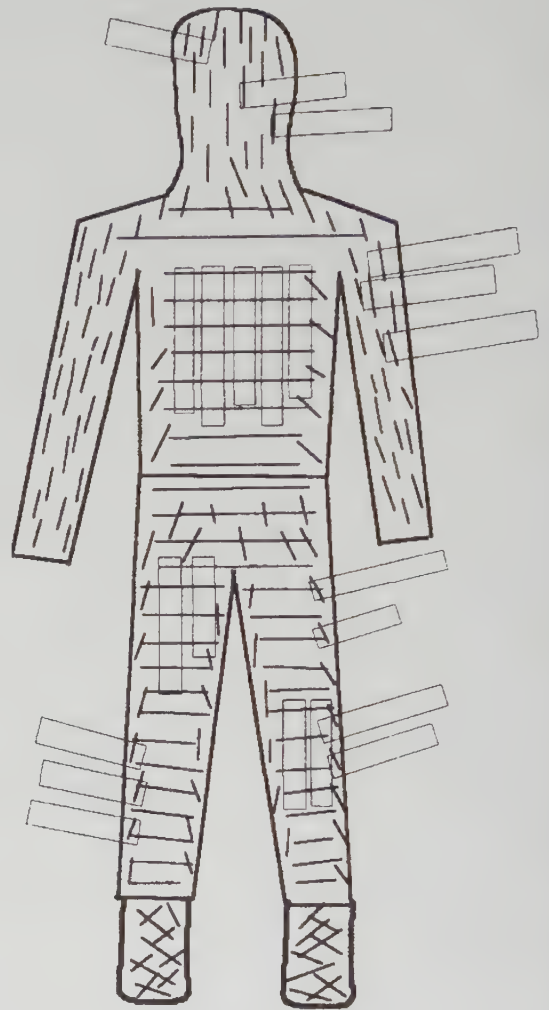
method of ghillie suit is designed to be mission specific. Along the way there has been a loss of focus on what a ghillie suit is when comparing the student/school environment to the operational ghillie suit. In reality, doing a belly down, very low to the ground stalk is going to happen in less than 1 percent of sniper operations. Slow and careful approach through concealment and vegetation is much more likely. The suit then is supporting the move into a Final Firing Position. Whether you use the traditional suit design or the attaching ghillie suit method the method of attaching garnish is the same. School solutions have included anything from gluing the individual strips of burlap and whatever else you use directly onto the uniform.

The use of netting that is stitched or glued to the uniform is a base for the garnish to be tied to. This method, however, adds great weight, bulk and waste to the suit as the knots offer little camouflage value but are great little sponges to soak up water and sweat. The net also tends to snag a lot more than the garnish does. When doing a traditional stalk where you are crawling and sliding through things that you sometimes can't see, that snagging can be a means to being spotted instantly. Students have been caught while dragging 30 feet of barbed wire and they didn't even know it. The net held without tearing while an individual strip of camouflage would have torn loose.

The image to the right is a depiction of the backside of a ghillie suit. The lines on the ghillie suit depict the direction of the lay of the strips. Not all of the strips hang down the length of the body. If you attach them all on the long axis of the suit, you will get a huge polar bear effect. The suit will have no "depth" at the top and will have poor texture. When you change the direction of the strip 90 degrees this makes the strip "lay out" more when standing and it lays down in the right direction. The different directions of the strip eventually will interlace the garnish. On several locations on the back of the suit, sew in pieces of 550 cord to tie in natural camouflage.

The strips of garnish should be 12-14 inches long for the vertical hanging strips. The pieces that are sewn 90 degrees to vertical should be between 8 and 12 inches long. From the knees down keep the length down to about 8 inches. For the strips that are attached to the boots, boot covers, gloves and hand-held items, the strips should be about 2-4 inches. The best method for attaching these strips is to sew them directly to the base material. Lay out the base cloth or uniform and draw the lines in place as shown above. Pre cut your strips of burlap and cloth and sew them in place one at a time. With everything pre-cut and marked this takes about 4-5 hours on a sewing machine. There is a great weight savings by individually sewing the strips on the suit.

Fire is a great danger to a sniper in a ghillie suit. Burlap dries out and is quite volatile when ignited. It may be a low risk situation, but if it does start on fire, you're toast fast. Obtain a fire retardant spray and treat the burlap strips before sewing them on. Scotchguarding the strips help keep the weight down if they are rained on. Scotchgard also aids in texturing the suit. Think of grass and vegetation after it rains. You can see the



individual raindrops on the grass. If the ghillie suit is soaking all of this up there will be a patch out there that is totally different in texture without these drops.

Veils long have been used by snipers to cover the area between the hat/hood and the optics on the rifle. They are difficult, however, to put in place when you have to do that in the final firing position. Here you are in the most dangerous place on earth, possibly under direct observation and you're stretching out a veil. It is really a huge pain in the butt. Good facial camouflage in the FFP tied in with a good gun bag that is heavily camouflaged will hide you quite well without having additional movement from placing a veil out. Veils also can greatly inhibit a clear line of vision to the target. The more the angle on this veil, the more the mesh will "compress" and block out vision of the target area. When a hat/hood, shoulder and arm camouflage, and good camouflage of the gun bag is tied in, it blends perfectly with the background.

Traditional ghillies can be one or two-piece suits. One-piece suits are hotter but offer better protection against abrasions and little bugs that like to crawl into the suit. Flight suits make a good base for a suit. Two piece suits offer better ventilation but cause problems when the sniper is trying to back up. Unless a crotch strap is sewn in, the jacket will ride up high and severely inhibit movement and the camouflage properties of the suit. One of the major problems of the traditional suit is that it is single purpose. Special Operations and any small unit missions is so equipment-laden these days that everything should have a dual purpose. The ghillie suit in either form is single purpose to assign any other duty to. However, the attaching ghillie suit cuts down on bulk and allows the rest of the field uniform to be used to carry those survival things that the sniper may need.

Remember the list of items to be carried earlier in this chapter. None of those items can be left behind. Deep in bad guy country are you going to leave behind emergency medical, signal, and food procurement items while you go on a penetration and take a shot? Well maybe the emergency food items but definitely not the rest. On most of the SF teams I served on, we had a saying, "If you put it down, don't expect to ever see it again." If you encounter enemy forces, or are tracked, you cannot come back to your equipment. Using a vest with the regular field uniform under the attaching ghillie suit, you maintain all of your survival kit components and the gear that you have in your pockets.

The only load re-configuring you have to do is carry in your sniper specific gear. The spotting scope and any other special equipment will fit into a little bag (the M-122 demolition charge bag works great). There is more information on these procedures later in this chapter under team operations. A final word on ghillie suits. Do not use what only works in a school environment. The different sniper schools do a fantastic job of teaching the craft. However, many times methods that are used to "pass" the course do not translate into real-world methodology. A good example is the use of canvas on the front of a ghillie suit. For a real world high risk mission, the lightest materials that will do the job is probably the only way to go. When you are already carrying 100 pounds of combat equipment, a 12-pound ghillie suit must be made lighter.

SELECTED MATERIAL ON SMALL UNIT MOVEMENT PROCEDURES

The focus of this book is on Hard-Target Interdiction and, therefore, the movement techniques associated with stalking a human target will not be addressed. These procedures are already well covered in the military sniper manuals. The material in *TC 31-20-4 Spec Opns Sniping* and *TC 23-14* (The U.S. Army sniper manual) is virtually identical as far as individual types of movement (walking, hands and knees crawl, high crawl, medium crawl and the low crawl) are concerned.

This section is going to deal with some lesser known information on small unit movement and some of the special skills associated with that movement. Some of the subjects that are going to be covered are:

- Silent Movement Techniques and Silent Movement Courses.
- Small Unit Immediate Action Drills

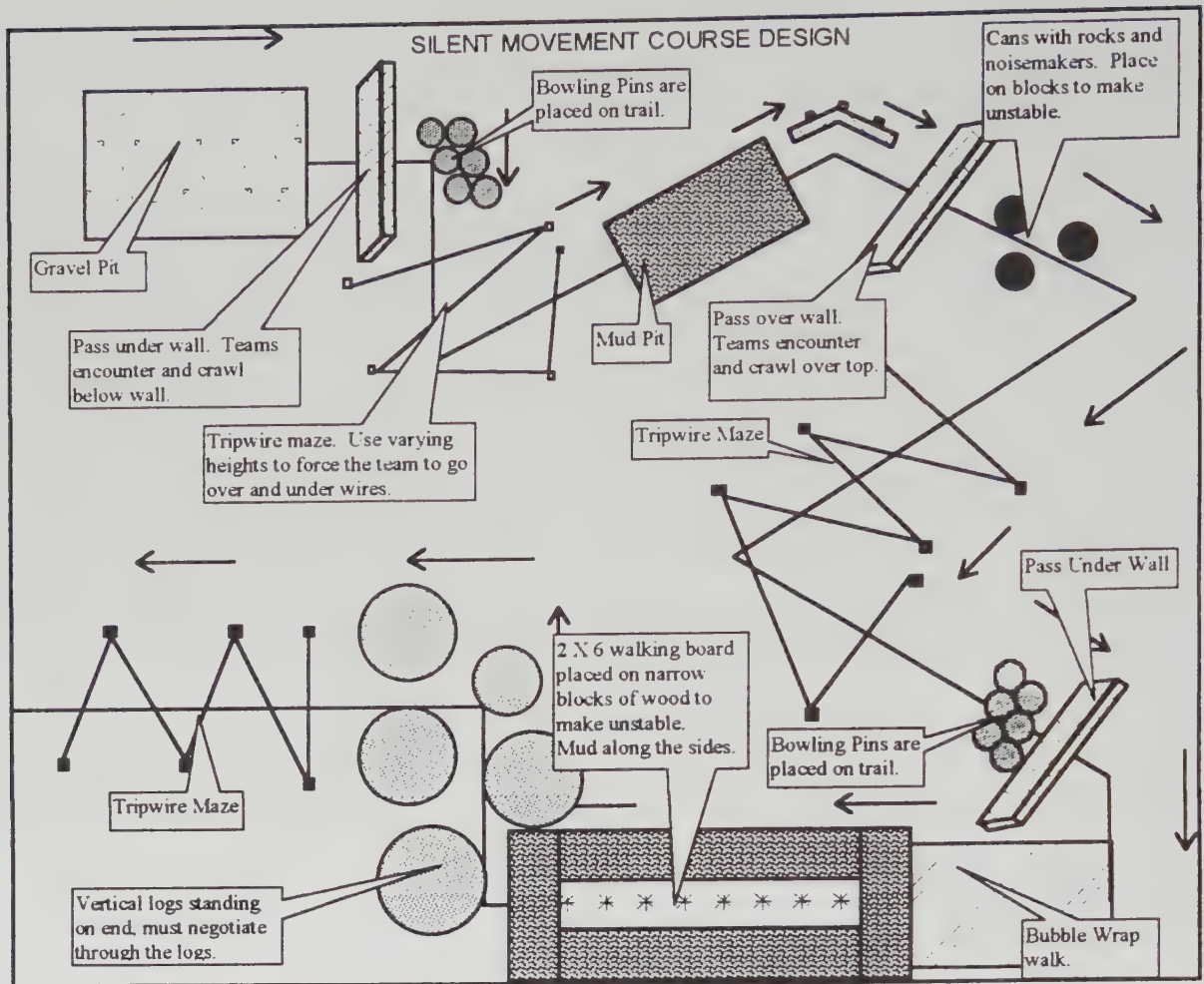
- Defeating Detection Devices.
- Counter Dog Techniques
- Tracking and Counter-Tracking Measures

Silent Movement Techniques apply to all kinds of unit movement. For this discussion we will cover how they can be used by small units (i.e. sniper teams) to negotiate through enemy territory during day and night. The art of silent movement involves many different aspects that requires the snipers to work out hand signals and control measures to use in the event operators lose their ability to see or hear. Silent movement requires that the operators carefully analyze their intended path first on a map and then through fingertip touch, smell, hearing and smell if necessary. The following is an extract from the *Special Operations Sniper Training and Employment* manual.¹

- Use binoculars and other optical devices to analyze the route that the team is going to take. Identify choke points or other potential danger areas to their movement. Keep in mind the factors that allow enemy forces to detect sniper operations in the area. Selecting the best route of advance is a constant changing process that starts with a careful analysis of the terrain, weather, and potential enemy situation.
- Work out any hand and arm signals that might be necessary. This is especially true at night when visual signals may not work. Decide which member will take the lead and how the team intends to stay in contact while moving through the route of advance. Signals should be worked out for the following events at a minimum:
 1. Finding obstacles to movement that will require a radical change of direction or negotiation to bypass or pass through the obstacle.
 2. Identifying the threat of the obstacle. Is it a simple impediment to movement or is it a physical threat to the team, i.e. mine, tripwire, etc.?
 3. Negotiating the obstacle. A pat on the boot could mean a low crawl is necessary. Touching the partner's head means you are going to go high over the obstacle. Touching the right or left shoulder means you may make a 90 degree right or left turn to bypass the obstacle or threat.
 4. Clearing the obstacle. This signal indicates to the partner that the lead is going to try to move the obstacle out of the way or render it inoperable. This depends on the type of obstacle of course. Tripwires never get cut but noisy cans can be moved aside once it is determined that they are not tripwired to a flare or explosive device.
 5. Signalling a Partner. When passing a hand signal to your partner a warning signal should be used so that he doesn't think your "bump" or "touch" wasn't an accident. A good signal is a squeeze of the wrist or ankle. That is followed by the actual signal that is intended to be passed.
- Use Stealth and Silent Movement Techniques. Stealthy and silent movement requires great patience and takes a long time to negotiate a route using these methods. At times when there is no visibility, operators have to be careful not to walk on each other. A good interval (about 1 meter) is necessary to avoid crowding the point man. These methods are very tiring and stressful. Drink a lot of water and take frequent rest halts. Some movement techniques include:
 1. Use cautious and deliberate movement. Each step must be "felt" prior to placing weight on the foot. A long blade of grass, even in total darkness can be used to detect obstacles to movement. As you pass the blade up and down you will feel the tension in the blade of grass changing as it hits trip wires or other items.
 2. When doing silent movement at night, use mild sensory deprivation by closing your eyes and inserting

hearing protection to “supertune” your visual and auditory sense. Fifteen to twenty minutes of this can highly tune these senses. If the movement is short, only the point man need do this. If it is going to be an all nighter, all members should do this. Do it on a rotational basis though so that all team members are not “blinded” at the same time.

3. Use frequent halts to listen and observe.
 4. Avoid unnecessary movement. Learn to be very efficient at all forms of motion. The point man is going to be very occupied and busy. The other members of the patrol are going to become bored and fidgety. Concentrate on what you see and what you can hear and feel. The other patrol members may detect things that the point man missed. Passing information back up to the point has always been difficult to do under high stress situations.
 5. Silence all noise-making personal gear. Whenever possible tape loose uniform parts like the trouser legs and arms. Tuck in the uniform jacket and take off any gloves. Remove head gear so that high riding trip wires may be felt with the hair on your head. Hitting a “hot” tripwire with your hat may set it off before you can cause enough tension to feel that wire through the hat.
 6. Pre-plan the next move. After negotiating one obstacle, carefully preplan and inform the rest of the patrol the direction and intention of the movement. DO NOT leave the trail members wondering which way you are going to go.
 7. Clear any foliage or debris from the intended direction of movement. The point man should brush lightly across the ground in front of him and remove any noise makers such as sticks, rocks or loose soil.
- Utilize Basic Elements of Walking Stealthily. Walking with stealth requires practice and it doesn’t hurt to have another sniper evaluate the process. Walking on loose gravel or on paper placed on grass is a good way to self-evaluate the effectiveness of your movement.
 1. Maintain balance. Keep as erect as possible, if possible. A deep crouch makes you tired and makes it easy to lose your balance.
 2. Shift weight gradually from one foot the next.
 3. Place the foot on the ground by placing the toe down first then rolling to the outer edge of the foot and then finally roll the foot down into the flat position. Once the foot is on the ground, slowly transfer weight from the rear foot to the front one. Do not place more weight than necessary to maintain balance on the front foot until you are ready to move the rear foot forward.
 4. Leading with one foot will increase the sensitivity of that foot. This means that you bring the trailing foot only up even with the lead foot. Once both feet are side by side, then lead off with your “strong” foot again.
 - Move Through Rubble and Debris. The point man has the responsibility of moving the patrol through the area without compromise. If there is only one man behind him, this isn’t too difficult. When there is more than one, communications to them concerning the surface texture of the ground is impossible. There is no way he can tell them how crunchy the ground may be. Because of this, he is responsible for removing the noisy items for their path. Use of the following guidelines:
 1. Test debris with your hand to determine if it is going to be a noisemaker or if it is solidly anchored to the ground.
 2. Remove debris that will break if another patrol member places his weight on it. Any piece of wood that can be moved should be moved. This of course doesn’t apply to branches light enough to move, but are overly large.
 3. Move forward as quickly as practical and as quietly as possible.



- Avoid moving through mud and muck. If it cannot be avoided, the boots should be wrapped with burlap rags or socks and then taped.
- Crossing sand can be fairly fast and leave little sign, unless the sand was groomed to detect enemy activity.
- Keep a low silhouette when moving over an obstacle. Avoid brushing or scraping against the obstacle. This is where taping the uniform down will help.
- Always maintain positive control of the weapon.

Silent movement courses are an excellent way of training the skills necessary for stealthy movement. Setting up a silent movement course has no limitations as to the degree of difficulty involved. A certain level of progression should be used. Start in the daytime, progress to dusk, and then practice completely at night. Take away certain senses as you progress. Starting in the daytime with full sight and hearing will teach an individual how to walk and how to handle obstacles. As you take away the senses of sight and hearing, he will rely and trust in his touch. Communications skills must be constantly practiced so that they become standard operating procedures for the team.

SELECTED IMMEDIATE ACTION DRILLS FOR SNIPER TEAMS

Immediate action drills (IADs) are those drills that the sniper team does automatically without hesitation when certain situations occur. Because the sniper team is much smaller than an infantry platoon, they have no firepower. Their first defense is stealth and hopefully they have a higher degree of sophistication in their movement and planning. Sometimes, however, the best procedures cannot overcome chance contact. For those situations IADs are used to break contact or to handle the emergency situation.

Artillery or Mortar Fire

This IAD for indirect fire is different from any current printed doctrine on reacting to indirect fire. The current printed material on this IAD is based on a conventional unit and is simply deadly to a smaller element. These methods were obtained from highly experienced personnel on the methodology of indirect fire and their procedures. The indirect fire procedures are universal with small changes in tactics. These following methods will work for 90 percent of the possible scenarios for small units coming under fire.

Common Sense Method and Avoidance Method

For lack of anything else, many personnel rely on the clock and distance method. In reality this was intended for large maneuver units and is a deadly practice for small elements. Small units can outthink the observer and the mortar or artillery section seeking to destroy it. The following procedure is recommended to handle indirect fire, mortar, or artillery. Since many sniper teams operate deep, it is likely to be quiet and the team should hear the guns firing. At that point the team has about 20 seconds to move (without frantic movement, to avoid further pinpointing) to cover. The act of lying on the ground in a depression will protect an individual from all but very close and direct hits. Remember that a gun firing does not mean you have been seen, yet. Frantic movement may reveal your position to the observer.

- Step 1. Go to ground.
- Step 2. Obtain cover within 20 seconds.
- Step 3. Wait for impact.

If there is no impact or impact is obviously not in your area, you are not under fire and may move on. However, remember that an observer is operating in the area.

- Step 4. Analyze the impact. There are three basic type missions that will be used against you. These are, along with their method of dealing with them:

Registration Missions

It is possible that you are in the proximity of a registration mission. Execute the above steps and wait. If there is a single registration mission and there is no adjustment to your position, you are simply too close to a point that a gun crew picked to register on. Avoid the areas that are obvious registration points. Examples include:

- Hilltops
- Road intersections
- Other easily defined points that do not move. These usually can be identified by a good map recon.

A registration mission can be identified by the following gun activity.

1. Single gun followed by a single impact.
2. Single gun being adjusted to registration.
3. Section firing one round followed by an adjustment.
4. End of Mission.

Step 5. Determine type of mission if possible. Remember you may or may not be under observation. You may have simply stumbled onto a registration mission. It may also be harassing and interdiction fire.

Step 6. Move out of the target area. Remember that you may or may not be under direct observation. A point to remember is that under any type mission that is close to your position, will be under observation by an observer. If your team has not been spotted yet, you may well gain the attention of the observer and bring intended fire upon yourself. After the end of the mission, move out of the area slowly and carefully, using maximum concealment and stealth. A general rule of thumb is to move at angles away from the point of impact—For example to the 8 o'clock or 4 o'clock direction with the point of impact being 12 o'clock.

Harassing, Searching and Traversing

At some point in your movement, you may be spotted or the observer may believe that he has a target of some type. He may not have a good location or direction of your movement. Under this situation, a harassing, searching, or traversing mission may be used against the team.

Harassing, searching, and traversing missions are characterized by the following fire patterns:

1. Initially the mission will be a four-gun mission that is on an open sheaf. These rounds will not be coordinated to land on a single point of the ground. Therefore, after the guns are heard, rounds will land approximately 40 meters apart on line or diagonally. This fire will be in front, rear, left, or right of the team.
2. Usually all rounds will impact simultaneously on an open sheaf pattern. There will be a 3-5 second delay as the next rounds are fired and a traversing and elevation change is made on each gun.
3. The pattern can start close to the guns and work away, or the pattern may land long and be adjusted to move closer to the guns. Generally, the mission is fired long and adjusted to move closer to the gun section.

Sniper team procedures are as follows:

Step 1. Upon hearing the guns fire (if possible), or on first impact, go to ground.

Step 2. If the guns were heard firing, you have at least 20 seconds. Use this time to find the best cover possible as fast as possible.

Step 3. Wait for impact.

Step 4. Analyze the impact. Determine the location of the impacts. If they are not directly on your position, your first reaction will be to move away from the fires. Avoiding these fires is a game of chance. You are playing against the OF who has spotted you as a target.

Step 5. Determine type of mission. Remember, if you are in shallow cover, you have a very good protection from all but the largest artillery fire. You may have to wait for 2 or 3 volleys to determine the fire pattern. This may start short and move directly away from the guns. It may start long and move directly toward the guns. It may also move on an angle away from or closer to the guns.

Step 6. Move out of the target zone. If the fires are moving away from your position, the observer does not have a good fix on your position (which is likely the case). If this is the case, use the fires to your advantage and move slowly and carefully out of the area. Do this on angles as with a registration mission. It is important to move on angles away from the original direction of travel. The observer may have fixed your direction of travel before the mission was fired. He may place fire on that direction of movement both up and down the trail of movement in hopes of picking the team off. Remember to move away from

the impact area. Remember that you may be under direct observation and the observer does not have a good fix. Do not foul this situation by making frantic bursts through the terrain. Movement attracts the eye, and this could bring adjustment that result in termination of the team's mission.

Point Mission

Under this situation, the team has been observed and the OF has a solid fix on the position of the team. The observer will likely fire a converged sheaf for effect on the first volley. Under this scenario, the team stands a good chance of survival if they are not directly in the impact area and are virtually scrubbed off in the first volley. Procedures are as follows.

Step 1. Go to ground. If the guns were heard firing, immediately look for a place to go.

Step 2. Obtain cover within 20 seconds (if guns were heard).

Step 3. Wait for impact. This is when you will discover if you were accurately spotted. If the fires are converged, you have been solidly fixed.

Step 4. Analyze the impact. A converged sheaf either on your location or away from it is a good indication of your being taken under fire for effect action.

Step 5. Determine type of mission. At this step, you will be convinced that you are under direct observation.

Step 6. Move out of the area. Use the obscuring effects of the mortars to your advantage and move as much as possible within the few seconds between volleys. One advantage is that an observer that observes only two personnel may not fire more than one volley to destroy the target. The wartime environment will indicate what his actions will be

Clock Method

Certainly the least desirable method. It was designed for large maneuver elements, not small units. If the team comes under light (1 to 5) rounds artillery or mortar fire, they may use the clock method to break contact. The low number of rounds indicates a registration adjustment, or a harassment mission. However, remember, you may not yet have been seen. The team leader will call the direction and distance for the team to proceed (12 o'clock is always the direction of travel). After the team has moved the designated distance, they will regroup. Team leader will designate the new route of march.

Rally Point Method

Should the team come under heavy fire (more than 5 rounds), the sniper team will use the last rally point (not the floating one) in effect, or when the team leader calls the rally point.

Immediate Action Drill, Sniper Fire

Should the team come under small arms fire, it is possible that the fire is from a sniper that is detached from his main body (LP/OP, Patrol, etc.). Light fire is defined as 1-5 rounds; however, a single well-placed round could indicate sniper fire. The team will immediately take cover and try to locate the sniper. If located the team can either have the team engage the target, fire and maneuver out of the range, or employ countersniper fire with the teams SWS. If the target cannot be located, the team can either fire and maneuver or withdraw using cover and concealment to the last rally point or to the pointed direction by commander.

Immediate Action Drill, Frontal Contact

If the sniper team should receive fire from the front or must initiate contact because of mutual compromise, the team will immediately return fire. If the team is moving in a file and find themselves in the above situation, then team will break contact using the "PEEL." This is written as if there are more than two men on the sniper team. HTI missions were written for a four-man cell. This is why there are more than two people written into these IADs.

Should the team run up on the enemy and have to initiate/return fire while in the file, they will use the “PEEL” to break contact. Point man and slack man will immediately dump one magazine and peel to the inside. Third and fourth man will take a step to the outside and dump magazines as the point and slack man are firing and splitting down the middle. This procedure is taken through out the entire team. The tail gunner will yell “Last man” as each man passes through him. During hours of darkness, personnel must “guide” members through the middle of the file. Last man will catch the personnel and place them in position, until he has to fire and depart. The peel will be executed 3 to 4 rollovers. Tail gunner and his overwatch will employ Claymores on a 6-inch fuse.

Immediate Action Drill, Flank Contact

Near Ambush

If the team encounters a heavy volume of fire from either flank and the enemy appears to within assaulting distance, the team is in a near ambush. Due to the closeness of the enemy, fire and maneuver would be useless—the only alternative is to assault through. The entire team will open fire at the enemy and run through—no one will stop until they are past the enemy. The team will regroup, form a defensive perimeter, place break contact mines and APMs. The senior coherent member will make a decision and direct the team on the actions to follow. As a rule, Claymore mines will be used after the fourth bound backward to break contact.

Far Ambush

Should the team receive fire on a flank from a distance too far from the assault, the team is in a far ambush. The team will immediately seek cover; the section closest to contact will lay down return fire. All other elements will orient 360 degrees guarding the front, rear, and open flank. (Always watch out for French Minuet-type ambushes). Team leader will direct the actions to take, i.e. fire and maneuver, flanking maneuvers, etc.

Immediate Action Drill, Chance Contact, Rear

Should the team receive light or sporadic fire from the rear, it is likely the team is in a chance contact, rear situation. Should the team take enemy fire from the rear, tailgunner and slack man will initiate/return fire while in the file, they will use the “PEEL” to break contact. Tailgunner and slack man will immediately dump one magazine and peel to the ahead and to the inside. Third and fourth (from the rear) man will take a step to the outside and dump magazines as the tail gunner and slack man are firing and splitting down the middle. This procedure is taken through out the entire team. The point man will yell “Last man” as each man passes through him. During hours of darkness, personnel must “guide” members through the middle of the file. Last man will catch the personnel and place them in position, until he has to fire and depart. The peel will be executed 3 to 4 rollovers. Point man and his overwatch will employ Claymores on a 6-inch fuse.

These immediate action drills are taken from IADs that were developed for use with Special Forces Operational Detachment Alphas (A-teams). The numbers of these teams vary from 4 to 12 depending on the mission. Their available firepower is only slightly more than what a sniper team may carry. In SF operations it is assumed that there is no indirect fire support and close air support may be more than an hour away, if at all.

DEFEATING DETECTION DEVICES

The method of defeating detection devices is obviously a sensitive one. This material is going to be open source and the methods in this sections are going to be only generalities. Detection systems are broken down into the following categories:

1. Light Amplification Devices.
2. Ground Sensor Systems.
3. Ground Surveillance Radar.
4. Thermal Imagers.
5. Sniper Detection Systems.

Light Amplification Devices

Light amplification devices (LAD) are both active and passive in nature. Today virtually every system that amplifies light is passive in nature. They can be enhanced with an infrared light source that makes them an active system. The difference between active and passive is that active systems can be detected and passive as yet can not be detected. Knowledge of the adversaries' capabilities is the best method of combating these systems. Currently in the United States, Generation III is the level of detection in use by military and police forces. These systems are also available to the general public. The most affordable are still Generation I (Vietnam-era) systems. These have the poorest resolution and shortest tube life. These are also the most commonly imported NVD. Defeating passive light amplification devices is done a number of ways. With all electronic systems, attacking them and getting past them is usually a game against the operator of that system. Here are a couple of recommendations:

1. Analyze the weather in the area. Rain, snow, and fog all greatly diminish all generations of LAD in the passive mode. Be wary though: by adding IR illumination, some of these bad conditions can be overcome to a certain degree. The sniper's own passive LADs will detect any IR illumination that is used. When IR illumination is encountered, freeze as you would with flare illumination. Then sink slowly to the ground.
2. Slow movement makes it harder for the enemy to detect your presence with passive and active LAD systems. By analyzing the terrain you can roughly determine what the observation range based on terrain and vegetation is going to be in your area. Move accordingly.
3. When using passive LADs in wooded areas where the overhead vegetation is dense, the detection capability of the best systems is greatly degraded.
4. IR flares are becoming widely used. Treat IR flares as you would a standard visible flare. Freeze and then sink slowly to the ground. It is best to freeze for the duration of the flare, but that may be hard to determine. Some flares last for a long time. At night flares fired from mortars and artillery are easily heard. Granted, snipers are usually operating behind enemy lines where indirect fire support isn't likely to be used for its explosive power. Those guns can easily be used to enhance rear area security with flare illumination, however. Best advice, when hearing the tubes shoot, freeze, and sink out of sight until you can determine what that gun fired.

Ground Sensor Systems

Ground sensor systems include all sensors that are seismic, magnetic, motion, or infrared beam sensors. The biggest problem with these sensors isn't necessarily defeating them, it is finding them before you trip one off. You have very little chance of detecting these systems when they are in the field. Your best bet is assuming that they are in use within certain distances around target areas. Your best source for the location of these is known enemy units that are in the field. Knowledge of the enemy's tactics and procedures will help you in determining if you should do countermeasures for these sensors.

Seismic sensors have major limitations in that there are discriminators built into these sensors. The discriminators are there to weed out false signals that come from animal and other random events that would trip the alarm. These discriminators are timer based in that if they sense two "events" within a certain period of time, it will trip the alarm. The trick is not causing more than two events within that time frame. Seismic sensors are the easiest of the mentioned systems to penetrate.

Magnetic, motion, and infrared beam sensors are nearly impossible to get past because it is usually not possible to detect their presence. Because of the iron in our weapons, magnetic sensors will get us. Pre-detecting an infrared beam is very difficult to do even with the best passive light amplification devices unless you get lucky enough to look directly into the source of the IR beam. You will not see the beam from the side.

Ground Surveillance Radars

Ground surveillance radars can detect soldiers and vehicles that are moving on the ground. The trick to defeating these sensors is defeating the operator that is using them. Of all mentioned systems, the GSR is the easiest to defeat with little sophistication required. Objects can only be detected along their line of sight and only when moving at a given speed or faster. The current U.S. systems take good operators to discriminate their readings accurately. Snipers can easily defeat these systems by crawling through defilade and using low crawl methods when on flat ground. Use as much natural masking as possible to place objects between suspected GSR sights and the sniper's body.

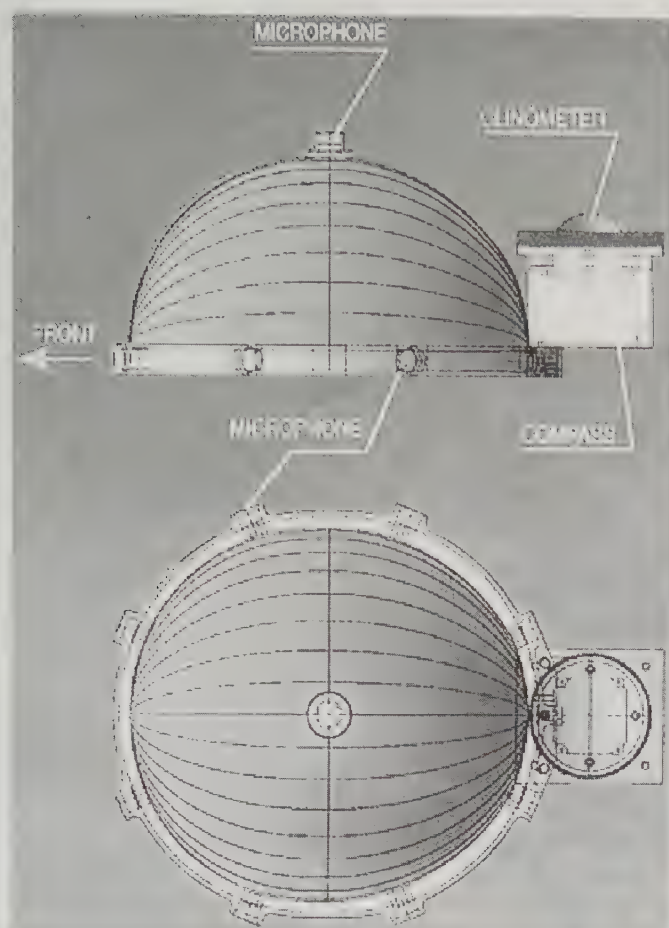
Thermal Imagers

Thermal imagers and forward looking infrared radar (FLIR) detect body heat and project that image on a screen for the operator to locate heat sources. Thermal imagers and FLIR are difficult to penetrate for the same reasons as sensor systems. The first problem is detecting their use. As with other systems, careful route planning and constantly making sure that you are masked to direct observation are good measures. One method that did work pretty good for fixed site countermeasures was the use of the forest services mylar fireproof survival tent. These tents are issued for forest firefighters. They deploy them when there is a danger of them being overrun by flames. The same properties that keep the person from being burned inside them keeps the heat source from leaking through the outside and being detected by thermal imagers or FLIR. Visual detection of these systems in use in the field is virtually impossible unless you spot the operators or the actual piece of equipment in daylight.

Sniper Detection Systems

These systems are just now coming into use. They are mostly as a result of major sniper problems in the Bosnian missions with the United Nations. Good snipers on the side of the U.N. forces could have solved the problems. Frequently countersnipers had targets that had fired shots but never could get the approval from higher command to shoot back. The fix to this problem was a number of detection systems that supposedly could detect the bullet in flight back to the gun. For the most part, these can be defeated by coordinated saturation shooting where other weapons systems cross fire to overload the system, or make the system so data-heavy that detecting the source of the sniper's shot is impossible. These systems have merit but the biggest problem obviously would be getting permission for countersnipers to return fire. This system can detect snipers operating in the area, but it can't shoot them for you. The best way to defeat these systems is to test reaction capability and time. It won't be hard for the people using this to find where the shot came from, but as with getting permission for CS shooters to shoot back, reaction is likely to be slow. This system is head mounted with a series of acoustic microphones and clinometers to detect direction and elevation above the target where the shots came from. Problem is, it can only work once a shot has gone off. Human countersniper operators are still the best method of denying snipers their operational capability.

The business of intentionally penetrating detection systems that are known to be in use is a tricky and dangerous one. You only know if you are successful if you make it through alive. The first indication that you were detected may be incoming direct or indirect fire. An enemy force may be laying in wait in an ambush position in front of you. The only thing that you can do is assume that you are under observation and move accordingly. Hopefully, intelligence can help out with known enemy positions that you can determine along with their known equipment capabilities and use your countermeasures as you see fit.



DEFEATING DOG TRACKER TEAMS

Within the sniper community there always has been a search for the methods involved in defeating dog tracker teams. The place to begin in this quest for the best countermeasures is in understanding how the tracker dogs do their stuff. Understanding their limitations and capabilities is one of the old areas of study in the countermeasure business. *TC 31-20-4 Special Operations Sniper Training and Employment* has some of the best information on this subject and I defer to that source. The following is from *TC 31-20-4*. I have changed some of the military wording to make it easier to understand and read.

There are three types of tracker dogs.

- Visual Dogs – These rely on their acute vision
- Search Dogs – These are allowed to run free and search using airborne scents
- Tracker Dogs – These dogs run on leashes and use ground scents

Many myths surround the abilities and limitations of canine trackers. The first and perhaps greatest myth is that tracking involves only the dog's sense of smell. Canine tracking involves a team, a merging of man and dog. Dogs use both their eyes and ears, the tracker uses his eyes and knowledge of the quarry. Together, they create an effective team that maximizes their strengths and minimizes their weaknesses. The sniper team is

not only trying to evade and outwit a dog but are also trying to out do the dog's handler. The most common breed of dog used is the German Shepherd. These dogs are trained to respond independently to a variety of situations and threats. Good tracking dogs are a rare and difficult to replace asset.

A human visual tracker assists the dog handlers in finding a track if the dog loses the trail. He can radio ahead to another tracker and give him an oral account of the track picture. A visual tracker is slower than dogs because he must always use his powers of observation, which creates fatigue. His effectiveness is limited at night.

A misconception is that dogs can smell molecular-level deposits left by the quarry. While it is true that blood, oil, or linked trails of material can be followed, this is not the primary scent that a dog tracks. Dogs smell microbes in the earth that are released from disturbed soil. The trail has no innate smell of a specific quarry, although trails do vary depending on the size and number of the quarry. For example, a scent is like the wake a ship leaves in the ocean, but no part of the ship is left in the wake. It is the white, foamy, disturbed water that is the trail. The result is entirely different from a point smell of a quarry such as sweat, urine, or cigarette smoke. The same training that makes tracking dogs adept at tracking a scent trail applies to finding a point smell.

Smelling is a highly complex process and many variables affect it. The most important element in tracking is "living" ground such as earth and grass that has living microbes in it and are disturbed by the quarry's passage. Artificial surfaces (concrete and tarmacadam) and mainly inorganic surfaces (stone) provide little or no living microbes to form a scent track.

A dog builds a scent picture of the person that he is tracking. Scent is short-lived and its life span is dependent upon the weather and the area that the person last passed through. The sun and the wind, as well as time, destroy the scent. There are both airborne and ground scents. Airborne scents can be blown away within minutes or a few hours. Ground scents can last as long as 48 hours under ideal conditions.

Wind and moisture are other major variables that affect tracking. Foggy and drizzly weather that keeps the ground moist is best. Too much rain can wash a trail away; depending on the strength of the trail, it takes persistent, hard rain to erase a scent trail. Usually, the scent is not washed away but only sealed beneath a layer of ground water. A short, violent rainfall could deposit enough water to seal the scent track, but after the rain stops and the water layer evaporates, the microbe trail would again be detectable by dogs. Hard, dry ground releases the fewest microbes and is the most difficult terrain for dogs to track on. A dog may also have difficulty following a trail on a beach or dusty path, but his human tracker could easily follow the footprints visually. Snipers must always remember they are being tracked by a man and a dog team.

Wind strength and direction are important factors in tracking. Basically, strong wind inhibits tracking a scent trail but makes it easier for a dog to find a point scent source such as a hide site. A general rule is that a dog can smell a man-sized source downwind out to 50 meters and a group-sized source such as a hide out to 200 meters under ideal conditions. Upwind, a source 1 meter away could be missed. A strong wind disperses microbes that arise from the ground, hindering the dog's ability to follow a trail. However, a strong wind increases the size of a point scent, helping a dog to find the target in an area search.

An inflexible rule for the life of a scent trail cannot be provided. In West Germany, the trackers rate their chance of following a trail that is more than three days old as negligible. Terrain, weather, and the sensitivity of the tracking dog are some of the many variables that affect the scent trail. A point smell will last as long as the target emits odors.

Although dogs have tremendous detection abilities, they also have their limitations. Following a scent trail is the most difficult task a tracking dog can perform. The level of effort is so intense that most dogs cannot work longer than 20 to 30 minutes at a time, followed by a 10 to 20 minute rest period. Dogs can perform this cycle no more than five or six times in a 24 hour period before reaching complete exhaustion. The efficiency of the search also decreases as the dog tires. In wartime, the situation will force the maximum from men and equipment, but times should remain consistent for dog endurance. In war or peace, dogs always give 100 percent effort. They enjoy tracking. If the snipers keep moving and stay out of the detection range of the human handlers, then they could outlast the dog-scent trackers.

When looking for sniper teams, trackers use wood line sweeps and area searches. A wood line sweep consists of walking the dog upwind of a suspected woodline or brush line. The key is upwind. If the wind is blowing through the woods and out of the wood line, trackers move 50 to 100 meters inside a wooded area to sweep the wood's edge. Since wood line sweeps tend to be less specific, trackers perform them faster. An area search is used when a team's location is specific such as a small wooded area or block of houses. The search area is cordoned off, if possible; the dog-tracker teams are brought online about 25 to 150 meters apart, depending on terrain and visibility. The handlers then advance, each moving their dogs through a specific corridor. The handler controls the dog entirely with voice commands and gestures. He remains undercover, directing the dog in a search pattern or to a likely target area. The search line moves forward with each dog dashing back and forth in assigned sectors.

Countermeasures

While dog and handler tracking teams are a potent threat, there are counters available to the sniper team. As always, the best defenses are basic infantry techniques: good camouflage and light, noise, and trash discipline. Dogs find a team either by detecting a trail or by a point source such as human waste odors at the hide site. It is critical to try to obscure or limit trails around the hide, especially along the woodline or area closest to the team's target area. Surveillance targets are usually on major axis of advance. "Trolling the woodlines" along likely looking roads or intersections is a favorite tactic of dog/tracker teams. When moving into a target area, the sniper team should take the following countermeasures:

- Remain as far away from the target area as the situation allows.
- Never establish a position at the edge of cover and concealment nearest the target area.
- Minimize the track. Try to approach the target area on hard, dry ground or along a stream or river.
- Urinate in a hole and cover it up. Never urinate in exactly the same spot.
- Deeply bury fecal matter. If the duration of the mission permits, use Meals, Ready to Eat (MRE) bags sealed with tape and take it with you.
- Never smoke.
- Carry all trash until it can be buried elsewhere or carried out.
- Surround the hide with a 3 to 5 centimeter band of motor oil to mask odor. Less effective but easier to carry is garlic. A dead animal can also be used to mask smell, although it may attract unwanted scavenger activity.

When dogs are being used against a sniper team, they use other odors left behind or around the team to find it. Sweat from exertion or fear is one of these. Wet clothing or material from damp environment holds in the scent. Soap or deodorant used prior to infiltration helps the dogs find the teams. When the sniper team arrives in its area of operations, move initially in a direction 90 to 170 degrees away from the objective. Objects or items of clothing NOT belonging to any of the team members are carried into the area in a plastic bag. Once the team is on the ground, drop this item of clothing or piece of cloth and leave it on a back trail when the team starts moving. This step can confuse a dog long enough to give the team a bigger lead in the chase. If the dogs are brought in late, the team's scent will have dissipated enough on the ground to maybe throw the dogs off.

If the tactical situation permits the team should try to avoid heavy foliage areas as these hold the scents longer. Of course the team needs these areas to remain concealed so the gains must be weighed against the possibility of visual compromise. When time and the tactical situation permits, move across an open area that the sun shines on during the day and has the potential to be windswept. The wind moves the scent and will eventually blow it away. The sun destroys the scent very rapidly.

Make changes in the direction at the open points of terrain to force the dog to cast for a scent. If dogs are

very close behind, moving through water does not confuse them as the scent will be hanging in the air above the water. Moving through water will only slow the team down. Throwing CS gas to the rear or using blood, spice mixtures, or any other concoctions will prevent a dog from smelling the team's scent, but it is not effective against a trained tracker dog.

Once method that works well against all dogs is using powdered glass on your trail. Take ordinary window pane glass and place it in a canvas bag. Hammer this glass into a fine powder. Pour the powdered glass into a sock. Carefully, roll the sock around in your hands, placing your scent on the glass. Put the glass into foot powder bottles so it is easily carried and used. Periodically, squirt the powdered glass back and forth along the trail. As the dogs sniff the glass into their lungs it causes them to bleed and fill with fluid. This will kill the dog within 30-45 minutes. Pain and other effects happen much quicker.²

While a dog will not be confused by water if he is close, running water such as a rapidly moving stream will confuse a dog if he is several hours behind. Areas with foliage, stagnant air and little sunlight will hold the scent longer. Avoid swampy areas as these areas hold the scent. Move through areas that are frequently traveled by other people, as this will confuse the team's scent picture to the dog. Team members may split up from time to time and relink up. This confuses the dog also. The best place for this is in areas frequently traveled by indigenous personnel.

If a dog-tracker team is on the sniper team's trail, they should not run because the scent will become stronger. The team may attempt to wear out the dog handler and confuse the dog, but should always be on the lookout for a good ambush site that it can fishhook into. If it becomes necessary to ambush the tracking party, fishhook into the ambush site and kill or wound the handler. This practice will allow the team to move off and away from the area while the rest of the tracking party tries to give assistance to the handler. Also, that dog will not work well with anyone other than his normal handler.

The team has options if caught inside the search area of a line search. The handlers rely on radio communications and often do not have visual contact with each other. If the team has been generally localized through enemy radio detection-finding equipment, the search net will still be loose during the initial sweep. A sniper team has a small chance of hiding and escaping detection in deep brush or in woodpiles. Larger groups will almost certainly be found. Yet the team may have the chance to eliminate the handler and escape the search net.

The handler hides behind cover with the dog. He searches for movement and then sends the dog out in a straight line toward the front. When the dog has moved about 50 to 75 meters, the handler calls the dog back. The handler then moves slowly forward and always from covered position to covered position. Commands are by voice and gesture with a backup whistle to signal the dog to return. If a handler is eliminated or badly injured after he has released the dog, but before he has recalled it, the dog continues to randomly search out and away from the handler. The dog usually returns to another handler or to his former handler's last position within several minutes. This time lapse creates a gap from 25 to 150 meters wide in the search pattern. Response times by the other searchers tend to be fast. Given the high degree of radio "chatter," the injured handler may be missed from the radio net for a while. Killing the dog before the handler will probably delay discovery only by moments. Dogs are so reliable that if the dog does not immediately return, the handler knows that something is wrong.

Taking on a dog in unarmed combat is an extreme hazard, but may be unavoidable. One dog can be easily dealt with using a knife or a large club. The sniper must keep very low and strike upward using the wrist, never use an overhand attack. Dogs are quick and are trained to go for the groin or the throat. If alone and faced with two or more dogs, the sniper should do his best to break contact without having to take on the dogs in unarmed combat.

Dog-tracker teams are a potent threat to a sniper team. While small and lightly armed, they can greatly increase the area that a rear area security unit can search. Due to the dog-tracker team's effectiveness and its lack of firepower, a sniper team may be tempted to destroy such an "easy" target. Whether a team should fight

or run depends on the situation and the team leader's decision. Eliminating or injuring the dog-tracker team only confirms to threat security forces that there is a hostile team operating in the area. The techniques for attacking a dog-tracker team should be used only in extreme situations or as a last measure.³

TRACKING METHODS AND PRINCIPLES

Sniper teams may or may not use tracking techniques. The intent of this material is to familiarize the reader with the general methodology and principles used in tracking humans. Through a better understanding of this, countertracking measures are easier to employ and develop. TC 31-20-4 is heavily quoted in this section.

Tracking is the art of being able to follow a person or an animal by the signs that they leave during their movement. It is next to impossible to move cross-country and not leave signs of one's passage. These signs, however small, can be detected by a trained and experienced tracker. A person who is trained in tracking techniques can use deception drills that can minimize telltale signs and throw off or confuse trackers who are not well trained or who do not have the experience to spot the signs of a deception.

As a tracker follows a trail, he builds a picture of the enemy in his mind by asking himself questions: How many people am I following? What is their state of training? How are they equipped? Are they healthy? What is their state of morale? Do they know they are being followed? To answer these questions, the tracker uses available indicators—that is, signs that tell an action occurred at a specific time and place. By comparing indicators, the tracker obtains answers to his questions.

Signs

Signs are visible marks left by an individual or an animal as it passes through an area. The tracker must know the following categories of signs:

- Ground Signs. These are signs left below knee level. All ground signs are further divided into large and small ground sign.
- Large Ground Sign. These are caused by the movement of 10 or more individuals through the area.
- Small Ground Sign. These signs are caused by the movement of one to nine individuals through the area.
- High Signs (also known as top sign). These are signs left above the knees. These are also divided into large and small top signs.
- Temporary Signs. These signs will eventually fade with time (e.g., a footprint).
- Permanent Signs. These signs require weeks to fade or will leave a mark forever (e.g., broken branches or chipped bark).

Tracking Indicators

These are any sign that the tracker discovers that are broken down into six different categories: Displacement, Stains, Weathering, Litter, Camouflage, and Immediate Use Intelligence.

Displacement

Displacement takes place when anything is moved from its original position. A well defined footprint in soft, moist ground is a good example of displacement. The footgear or bare feet of the person who left the print displaced the soil by compression, leaving an indentation in the ground. The tracker can study this sign and determine several important facts. For example, a print left by worn footgear or by bare feet may indicate lack of good equipment. Displacement can also result from clearing a trail by breaking or cutting through heavy vegetation with a machete. Such trails are obvious to the most inexperienced tracker. Individuals may unconsciously break more branches as they move behind someone who is cutting. Displacement indicators can also be made by persons carrying heavy loads who stop to rest. Prints made by deep box edges can help to

identify the load they are carrying. When loads are set down at a rest halt, they usually crush grass and twigs. A reclining man can also flatten the vegetation.

- **Analyzing Footprints.** Footprints can indicate direction, rate of movement, number, and sex and whether the individual knows he is being tracked.
 1. If the footprints are deep and the pace is long, rapid movement is apparent. Extremely long strides and deep prints with toe prints deeper than the heel prints indicate running.
 2. Prints that are deep, short, and widely spaced, with signs of scuffing or shuffling indicate the person who left the print is carrying a heavy load.
 3. If the patrol members realize they are being followed, they may try to hide their tracks. Persons walking backwards have a short and irregular stride. The prints have an unnaturally deep toe, and soil is displaced in the direction of movement.
 4. To determine the sex of a member of the party being followed, the tracker analyzes the size and position of the footprints. Women tend to be pigeon-toed, while men walk with their feet straight ahead or pointed slightly to the outside. Prints left by women are usually smaller and the stride is usually shorter than that taken by men.

Determining Key Prints

Normally, the last man in the patrol being followed will leave the clearest foot prints. These are the key footprints. The tracker will cut a stick to match the length of the prints and notch it to show the length and widest part of the sole. He can then study the angle of the key prints in relation to the direction of march. He looks for an identifying mark or feature, such as worn or cut boot soles, to identify the key print. If the trail becomes vague, erased, or merges with another, the tracker can use his stick measuring device to identify the key prints. This method helps him stay on the trail.

By using the “box method,” a tracker can count up to 18 persons. There are two ways the tracker can use the box method:

1. The most accurate way is to use the stride as a unit of measure when determining key prints. The tracker uses these prints and the edges of the road or trail to box in an area to analyze.
2. The tracker may also use the 36 inch box method if key prints are not evident. To use this method, the tracker uses the edges of the road or trail as the sides of the box. He measures a cross section of the area that is 36 inches long. He then counts each footprint in the box and divides this by two. This method gives a close estimate of the number of individuals who made the prints. This system is not as accurate as the stride method.

Recognizing other Signs of Displacement

Foliage, moss, vines, sticks, or rocks that are scuffed or snapped from their original position form valuable indicators. Broken dirt seals around rocks, mud or dirt moved to rocks or other natural debris, and water moved onto the banks of rivers are good indicators. Vines may be dragged, dew droplets displaced, or stones and sticks overturned to show a different color underneath. Grass or other vegetation may be bent or broken in the direction of movement.

The tracker inspects all areas for bits of clothing, threads, or dirt from footgear that can be torn or can fall and be left on thorns, snags, or the ground.

Flushed from their natural habitat, wild animals and birds are another example of displacement. Cries of birds excited by unnatural movement is an indicator. The tops of tall grass or brush moving on a windless day indicates that someone is moving the vegetation.

Changes in the normal life of insects and spiders may indicate that someone has recently passed. Valuable clues are disturbed bees, ant holes covered by someone moving over them, or torn spider webs. Spiders often spin webs across open areas, trails, or roads to trap flying insects. If the tracked person does not avoid these webs, he leaves an indicator of his passage.

If the person being followed tries to use a stream to cover his trail, the tracker can still follow successfully. Algae and other water plants can be displaced by lost footing or by careless walking. Rocks can be displaced from their original position or overturned to indicate a lighter or darker color on the opposite side. The person entering or exiting a stream creates slide marks or footprints. They may also scuff the bark of roots or trees that are on the side of the bank. Normally, a person or animal seeks the path of least resistance; therefore, when searching the stream for an indication of departures, trackers will find signs in open areas along the banks.

Stains

A stain occurs when any substance from one organism or article is smeared or deposited on something else. The best example of staining is blood from a profusely bleeding wound. Bloodstains often appear as spatters or drops and are not always on the ground. They also appear smeared on leaves or twigs of trees and bushes. The tracker can also determine the seriousness of the wound and how far the wounded person can move unassisted. This process can lead the tracker to enemy bodies or indicate where they have been carried. By studying the bloodstains, the tracker can determine the wound's location.

- If the blood seems to be dripping steadily, it probably came from a wound on the trunk.
- If the blood appears to be slung toward the front, rear, or sides the wound is probably in an extremity.
- Arterial wounds appear to pour blood at regular intervals as if poured from a pitcher. If the wound is venous, the blood pours steadily.
- A lung wound deposits pink, bubbly, and frothy bloodstains.
- A bloodstain from a head wound appears heavy, wet, and slimy.
- Abdominal wounds often mix blood with digestive juices so the deposit has an odor and is light in color.

Any body fluids such as urine or feces deposited on the ground, trees, bushes, or rocks will leave a stain.

On a calm, clear day, leaves of bushes and small trees are generally turned so that the dark top side shows. However, when a man passes through an area and disturbs the leaves, he will generally cause the lighter side of the leaf to show. This movement is also true with some varieties of grass. Moving causes an unnatural discoloration of the area, which is called "shine." Grass or leaves that have been stepped on will have a bruise on the lighter side.

Staining can occur when muddy footgear is dragged over grass, stones, and shrubs. Thus, staining and displacement combine to indicate movement and direction. Crushed leaves may stain rocky ground that is too hard to show footprints. Roots, stones, and vines may be stained where leaves or berries are crushed by moving feet.

The tracker may have difficulty determining the difference between staining and displacement since both terms can be applied to some indicators. For example, muddied water may indicate recent movement. Displaced mud also stains the water. Muddy footgear can stain stones in streams; and algae can be displaced from stones in streams and can stain other stones or the bank. Muddy water collects in new footprints in swampy ground. However, the mud settles and the water clears with time. The tracker can use this information to indicate time. Normally, the mud clears in about one hour, although time varies with the terrain. Since muddied water travels with the current, it is usually best to move downstream.

Weathering

Weathering either aids or hinders the tracker. It also affects indicators in certain ways so that the tracker can determine their relative ages. However, wind, snow, rain or sunlight can erase indicators entirely and

hinder the tracker. The tracker should know how weathering affects soil, vegetation, and other indicators in the area. He cannot properly determine the age of indicators until he understands the effects that weathering has on trail signs.

By studying weathering effects on indicators, the tracker can determine the age of the sign. For example, when bloodstains are fresh, they are bright red. Air and sunlight first change blood to a deep ruby-red color, then to a dark brown crust when the moisture evaporates. Scuff marks on trees or bushes darken with time. Sap oozes on trees and then hardens when it makes contact with the air.

Weather greatly affects footprints. By carefully studying this weathering process, the tracker can estimate the age of the footprint. If particles of soil are just beginning to fall into the print, the tracker should become a stalker. If the edges of the print are dried and crusty, the prints are probably about an hour old. This process varies with terrain and is only a guide. A light rain may round the edges of the print. By remembering when the last rain occurred, the tracker can place the print into a time frame. A heavy rain may erase all signs.

Trails exiting streams may appear weathered by rain due to water running from clothing or equipment into the tracks. This trait is especially true if the party exits the stream single file. Then, each person deposits water into the tracks. The existence of a wet, weathered trail, slowly fading into a dry trail indicates the trail is fresh.

Wind dries out tracks and blows litter, sticks, or leaves into prints. By recalling wind activity, the tracker may estimate the age of the tracks. For example, the tracker may reason “the wind is calm at the present, but blew hard about an hour ago. These tracks have litter blown into them, so they must be over an hour old.” However, he must be sure that the litter was blown into the prints and not crushed into them when the prints were made.

Wind affects sound and odors. If the wind is blowing down the trail (toward the tracker) sounds and odors may be carried to him. If the wind is blowing up the trail (away from the tracker), he must be extremely cautious since wind also carries sounds toward the enemy. “Remember olfactory and auditory target indicators? A sniper team being tracked can use their sense to detect the possibility of a tracker on their backtrail.”⁴ The tracker can determine wind direction by dropping a handful of dust or dried grass from shoulder height. By pointing in the same direction the wind is blowing, the tracker can localize sounds by cupping his hands behind his ears and turning slowly. When sounds are the loudest, the tracker is facing the point of origin.

In calm weather (no wind), air currents that may be too light to detect can carry sounds to the tracker. Air cools in the evening and moves downhill toward the valleys. If the tracker is moving uphill late in the day or night, air currents will probably be moving toward him if no other wind is blowing. As the morning sun warms the air in the valleys, it moves uphill. The tracker considers these factors when plotting patrol routes or other operations. If he keeps the wind in his face, sounds and odors will be carried to him from his objective or from the party being tracked.

The sun should also be considered by the tracker. It is difficult to fire directly into the sun. If the tracker has the sun at his back and the wind is in his face, he has a slight advantage.

Litter

Litter consists of anything not indigenous to the area that is left on the ground. A poorly trained or poorly disciplined unit moving over terrain is apt to leave a trail of litter. Unmistakable signs of recent movement are gum or candy wrappers, ration cans, cigarette butts, remains of fires, urine, human feces, and bloody bandages. Rain flattens or washes litter away and turns paper into pulp. Exposure to weather can cause ration cans to rust at the opened edge. Then the rust moves towards the center. The tracker must consider weather conditions when estimating the age of the litter. He can use the last rain or strong wind as the basis for a time frame.

The sniper should also know the wildlife in the area. Even sumps, regardless of how well camouflaged, are a potential source of litter. This type of source is due to the fact that many animals can find the sump and dig it up for food. The best policy you can follow is to take all trash out with you.

Camouflage

Camouflage applies to tracking when the party being followed uses techniques to baffle or slow the tracker. Walking backward to leave confusing prints, brushing out trails, and moving over rocky ground or through streams are forms of tracking camouflage. These activities can indicate a well trained adversary.

Immediate Use Intelligence

The tracker combines all indicators and interprets what he has seen to form a composite picture for on-the-spot intelligence. For example, indicators may show contact is imminent and this requires extreme stealth.

The tracker avoids reporting his interpretations as facts. He reports what he has seen, rather than stating that these things exist. There are many ways a tracker can interpret the sex and size of the party, the load, and the type of equipment. Time frames can be determined by weathering effects on the indicators.

Immediate use intelligence is information about the enemy that can be used to gain surprise, keep him off balance, or to keep him from escaping the area entirely. The commander may have many sources of intelligence such as reports, documents, or prisoners of war. These sources can be combined to form indicators of the enemy's last location, future plans, and destination.

Tracking gives the commander definitive information on which he can act on immediately. For example, a unit may report that there are no men of military age in a village. This information is of value only if it is combined with other information to make a composite enemy picture in the area. Therefore, a tracker who interprets trail signs and reports that he is 30 minutes behind a known enemy unit, moving north and located at a specific location, gives the commander information on which he can act.

COUNTERTRACKING METHODS AND PRINCIPLES

Countertracking is an art that requires great patience. When a member of a small unit is heavily laden with a patrol rucksack weighing 80 pounds or more, a combat vest, and his individual weapons, countertracking measures quickly become a low priority event. That is unfortunate. If a team does pick up trackers on their trail and they are not wary of this threat, it is likely that the only notice they will get of these human trackers is in the form of an ambush. Countertracking measures fall into two categories:

- **Passive Measures.** Passive measures are those things that are done routinely throughout the patrol to reduce the team's visual footprint through the area.
- **Active Measures.** Active measures are events that the team does to actively detect a tracker's presence and shaking off trackers that are on their trail. This includes ambushing the trackers if necessary.

It takes many years of training to develop a human tracker that can keep up with a small unit that is moving through an area. The sloppier that movement is, however, the easier it is going to be for a tracker to keep up and plot their intended direction. Remember the countermeasures discussed against mechanical and electronic detection devices? That was with knowledge of the enemy and terrain and the capabilities and limitations of those devices. The same holds true when operating against human trackers. Sniper teams entering a target area hopefully will have some intelligence estimate of the capability of trackers in their area. In Vietnam, recon operators under Military Assistance Command, Vietnam Studies and Observations Group (MACVSOG) encountered trackers many times once the enemy forces were onto their method of infiltration and their selection criteria for landing zones in enemy held areas. Enemy counterreconnaissance efforts heavily favored human trackers to run down these teams.

There are two categories of human trackers. These are the combat trackers and professional trackers. The combat trackers look ahead for series of signs and do not necessarily go from sign to sign. Professional trackers go from sign to sign. If they cannot find any sign, they will stop and search until they find one. The only way

to lose a trained professional tracker is to fishhook into an area and ambush him. If an enemy tracker finds tracks of a very small unit (two to six men) he may assume that a very specialized unit is operating in the area. He may assume a special reconnaissance team or a sniper team. However, a knowledge of tracking methods and countertracking measures enables the sniper team to survive by remaining undetected.

As with the dogs, to confuse the combat tracker and throw him off the track, the sniper always starts his movement away from his objective. He travels in a straight line for about an hour and then changes direction. Changing will cause the tracker to cast in different directions to find the track.

Evasion

Evasion of the tracker or pursuit team that is locked in on a team is a difficult task that requires use of immediate action drills. These IADs are in the form of a carefully planned and executed hasty ambush. Getting into a gunfight is the last resort for the team as it may mean the end of their mission. Abort criteria that is established in mission planning will dictate most of these scenarios. The team leader will be responsible for those not pre-set in the mission planning phase.

Camouflage

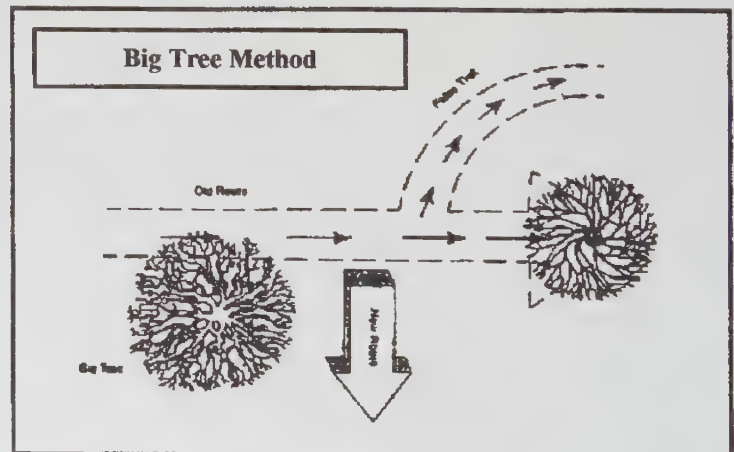
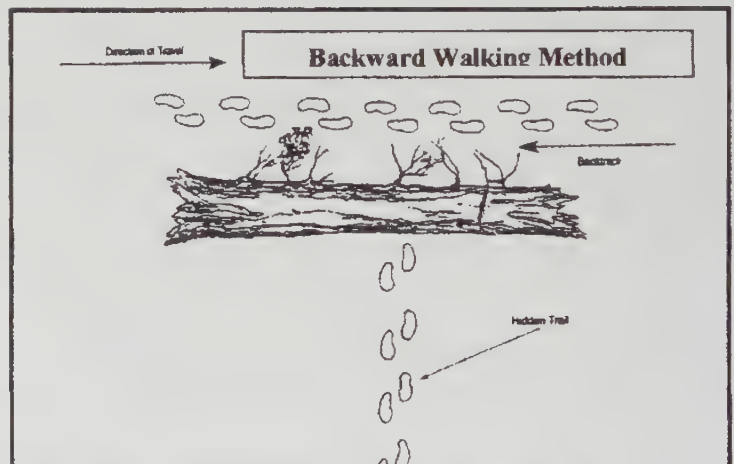
The followed party may employ most-used and least-used routes to cover its movement. It also loses travel time when trying to camouflage the trail.

- **Most-Traveled Routes.** Movement on lightly-traveled sandy or soft trails is easily tracked. However, a person may try to confuse the tracker by moving on hard surfaced, often traveled roads. They may try to merge their tracks with the myriad of tracks on the trail. These routes should be carefully examined. If a well defined approach leads to the enemy forces, it will probably be mined, ambushed, or covered by snipers.
- **Least-Used Routes.** These routes avoid all manmade trails or roads and confuse the tracker. They are normally magnetic azimuths between two points. The tracker can use the proper concepts to follow the party if he is experienced and persistent.

Reduction of Trail Signs

A sniper who tries to hide his trail moves at reduced speed. The experienced tracker will gain time on the sniper in this case. The sniper team can use the following methods to reduce trail sign:

- Wrap footgear with rags or wear soft-soled sneakers that make footprints rounded and



less distinctive. Be careful when wrapping rags or burlap around the boots. This can leave visual and tactile target indicators of the teams' passage.

- Brush out the trail. This process can rarely be done without leaving signs of brushing out a trail.
- Change into footgear with a different tread immediately following a deceptive maneuver. Scent alteration on these different shoes works well to shake off a tracker dog team.
- Walk on hard or rocky ground.

Deception Techniques

Evading a skilled and persistent enemy tracker requires skillfully executed maneuvers to deceive the tracker and cause him to lose the trail. An enemy tracker cannot be outrun by a sniper team that is carrying equipment because he travels light and is escorted by enemy forces designed for pursuit. The size of the pursuing force dictates the sniper team's chances of success in employing ambush type maneuvers. Sniper teams use some of the following techniques in immediate action drills and deception drills.

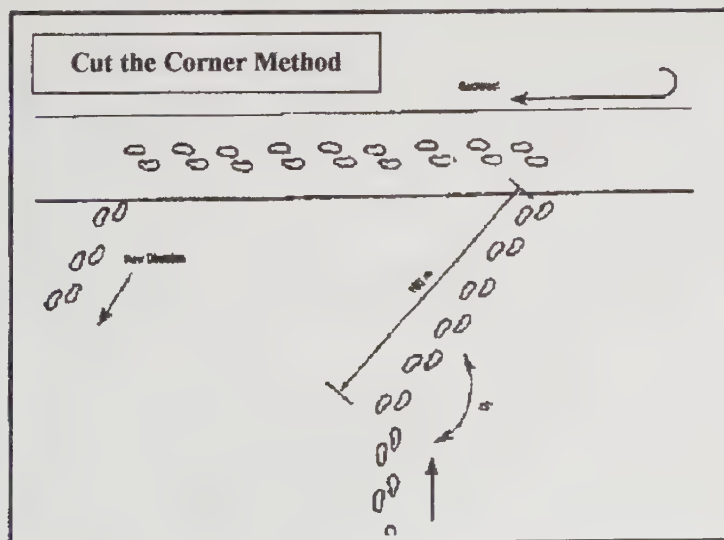
Backward Walking

One of the most basic techniques is walking backward in tracks already made. You then step off the trail onto terrain or objects that leave little to no sign. Skillful use of this maneuver causes the tracker to look in the wrong direction once he has lost the trail.

Remember earlier in the text that special emphasis is given on the shape of footprints. One of the distinct patterns that are easily recognized is walking backwards. Trying to do this method with a load is nearly impossible to execute and successfully shake a tracker.⁵

Big Tree Method

A good deception tactic is to change directions at large trees. To change, the sniper moves in any given direction and walks past a large tree (12 inches or larger diameter) from 5 to 10 paces. He carefully walks backward to the forward side of the tree and makes a 90-degree change in the direction of travel, passing the tree on its forward side. This technique uses the tree as a screen to hide the new trail from the pursuing tracker. A variation used near a clear area would be for the sniper to pass by the side of the tree that he wishes to change direction to on his next leg. He walks past the tree into a clear area for 75 to 100 meters and then walks backward to the tree. At this time he moves 90 degrees and passes on the side away from the tracker. This method could cause the tracker to follow his sign into the open where, when he loses the track, he might cast in the wrong direction for the right track.



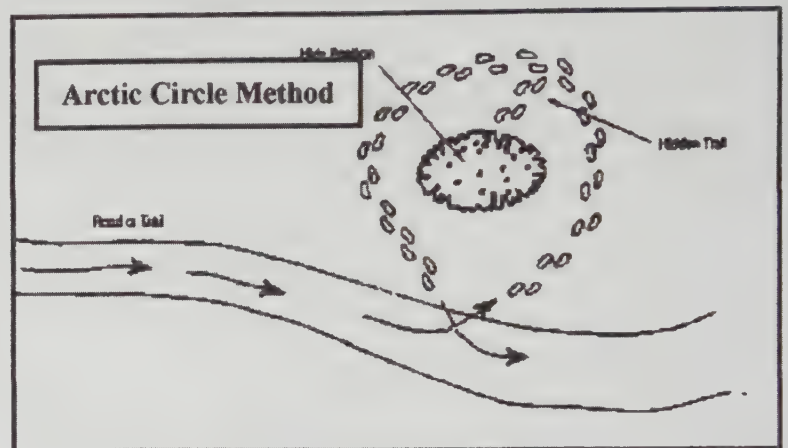
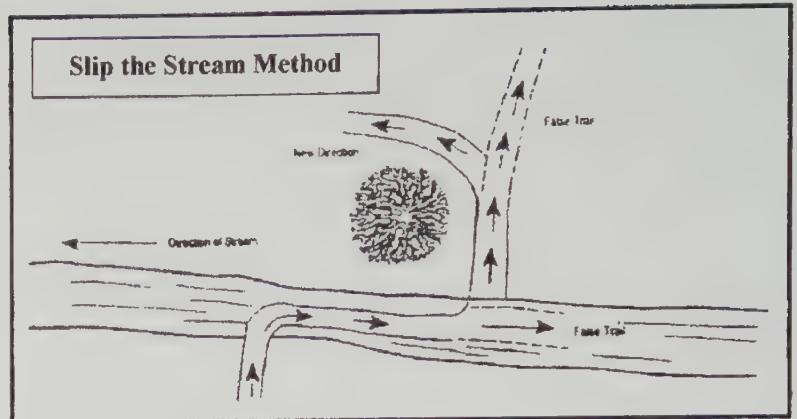
Cut the Corner Method

The sniper team uses this deception method when approaching a known road or trail. About 100 meters from the road, the team changes its direction of movement, either 45 degrees left or right. Once the road is reached, the team leaves a visible trail in the same direction of the deception for a short distance down the road. The tracker should believe that the team "cut the corner" to save time. The team backtracks on the trail to the point where it entered the road and then carefully moves down the road without leaving a good trail. Once the desired distance is achieved, the team

changes direction and continues movement. A combination using the big tree method here would improve the effectiveness of this deception.

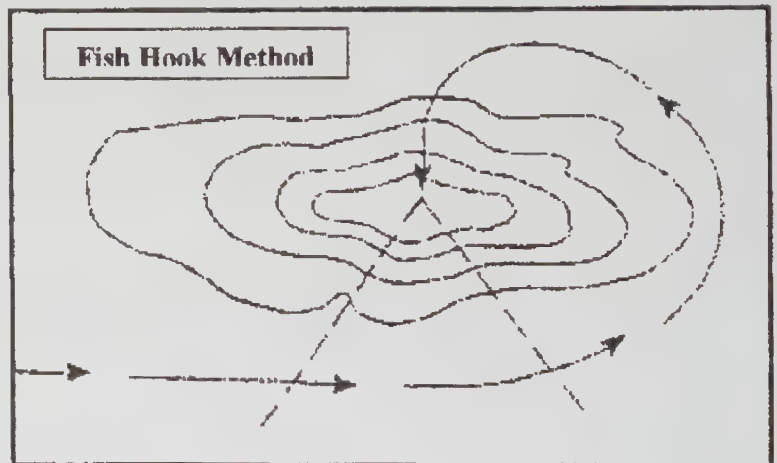
Slip the Stream

The sniper team uses this deception when approaching a known stream. It executes this method the same as the “cut the corner” maneuver. The team establishes the 45-degree deception maneuver upstream, then enters the stream. The team moves upstream to prevent floating debris and silt from compromising its direction of travel, and the team establishes false trails upstream if time permits. Then it moves downstream to escape since creeks and streams gain tributaries that offer more escape alternatives. False exit points can also be used to further confuse the tracker. However, the sniper must be careful to cause a false exit to avoid giving away their intended direction of travel.



Arctic Circle

The team uses this deception in snow covered terrain to escape pursuers or to hide a patrol base. It establishes a trail in a circle as large as possible. The trail that starts on a road and returns to the same start point is effective. At some point along the large circular trail, the team removes snowshoes (if used) and carefully steps off the trail, leaving one set of tracks. The large tree maneuver can be used to screen the trail. From the hide position, the team returns over the same steps and carefully fills them with snow one at a time. This technique is especially effective if it is snowing.



Fishhook Method

The team uses this technique to double back on its own trail in an overwatch position. It can observe the back trail for trackers or ambush pursuers. If the pursuing force is too large to be destroyed, the team strives to eliminate the tracker. It uses hit and run tactics, then moves to another ambush position. The terrain must be used to advantage.

Dog and visual trackers are not infallible; they can be confused with simple techniques and clear thinking. The sniper should not panic and try to outrun the dog or visual tracker. It only makes it easier for the tracking party. The successful sniper keeps his head and always plans two steps ahead. Even if trackers are not in the area, it is best to always use countertracking techniques. This prevention will prevent possible grief in the long run.⁶

Active Counter Measures

These are measures that openly attack the tracking force. They are intended to be destructive in nature and do not conceal the sniper team. These are deterrents to further pursuit.

- Anti-Pursuit Munitions (APM). When the team believes itself to be tracked it can employ APMs. The team must remember that once these are laid out they can no longer backtrack on their trail, nor can they cross it. They may walk into their own booby traps.
- Tracking animals can be soundly defeated by the use of crushed glass as has been detailed earlier.
- Hasty Ambush. Should the team feel that it is being tracked, they can employ a hasty ambush. This is done by the teaming the skip method and moving back opposite of the direction of movement and quickly getting into a hasty ambush posture. Care must be taken as not to alert the trackers. The team leader will initiate the ambush with his weapon. Claymores are also good.
- M-18A1 Claymore. The team may employ Claymores in a mechanical ambush situation. To do this, set up a hasty perimeter. These mines should be rigged with trip-wires. Employ aggressive anti-tracking measures from this point on, because the trackers will either give up or drive much harder.

OBSERVATION

Observation skills for a sniper team are just as important for their defense and protection as they are for locating, identifying, and indexing targets. The team looks for all of the indicators that they use to ensure that they are not seen. Observation skills are used to locate any possible threat from infiltration, through target engagement and back to the exfiltration. The team uses their naked eye and any optical instrument to support and enhance their ability to see and detect the threat.

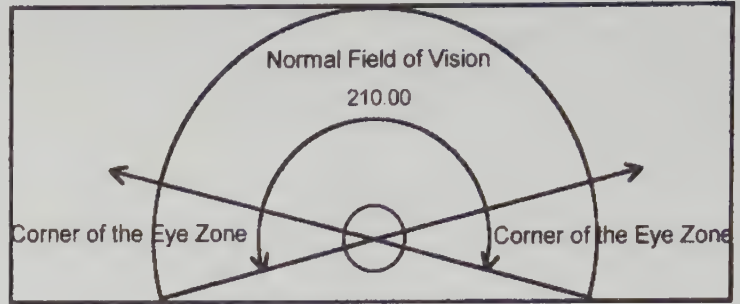
U.S. military snipers have many good optics to support the observation requirements for their mission. They have two different types of binoculars (M19 and M22), two day optical systems (ACOG and the M-3 or M-1 rifle scope), spotting scopes (M-49, M-144, Swarovski) and the night vision systems (AN/PVS-7B, AN/PVS-10, AN/PVS-4, SIMRAD, etc.). When teams search for threats and targets they can use two different search methods. These are the hasty and the detailed search.

The hasty search is the search method most commonly used by operators while in movement to detect threats and determining their route of advance. When searching for threats, remember that while the eyes are moving, they are much less efficient at determining moving targets. To conduct the hasty search you look into the field of view and move the eyes from point to point starting in close and going back and forth. You pause your eye movement at points along the way and let your eyes “float” over that particular field of vision. Start in close and as you screen back and forth, increase your visual range. The area around the peripheral field of vision is the most sensitive to movement. This method is called “seeing out of the corner of the eye.”

Have you ever noticed when someone is walking by you how fast you catch them in your extreme field of vision? For the best sensitivity of this method, the eye must be focused on a distant point. Then the side vision sensitivity is greatly increased. Well trained and seasoned observers are able to detect slight motion at the extreme field of view and react to it much faster than non-trained personnel. Personnel trained in Close Quarters Combat find this skill invaluable. CQB training enhances and enforces this vision technique although the ranges are much closer.

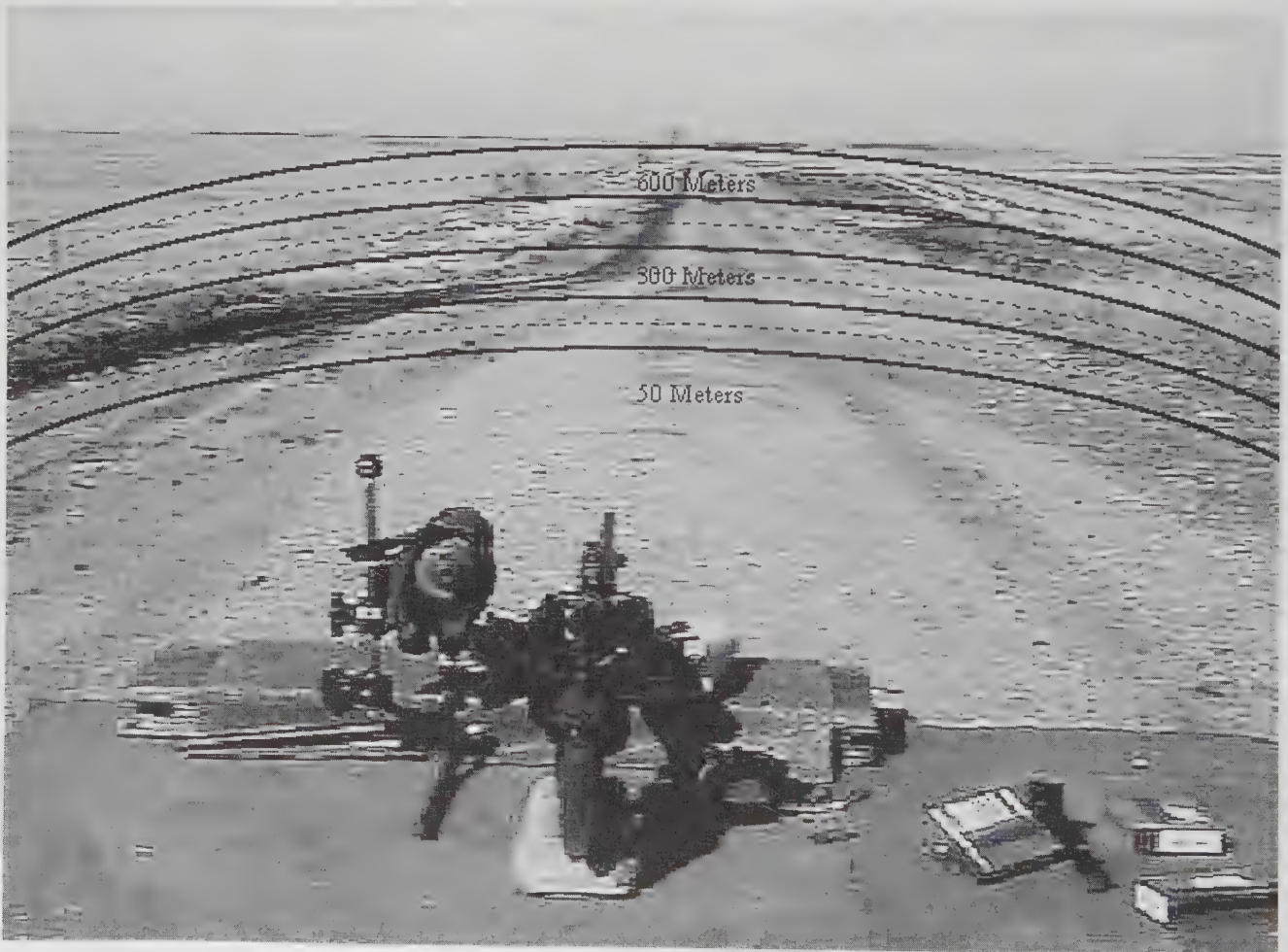
A good method for practicing and refining this method is to sit in a mall or an airport in the center aisle (provided there are benches). Focus your vision on a point down the center of the aisle. Notice how

fast and how sensitive your eyes are to the activity of people that are going by you from behind. When you pick your spot, notice the door frame of a store or other object that is more than 90 degrees to your straight forward field of vision. Persons with good field of vision can see more than 210 degrees of their forward view.



If the team member spots something of interest, he switches to an optical instrument to execute a detailed search. The detailed search is a systematic search of the field of view by breaking the target area into bands. These bands are 50 meters deep and as wide as the observer wishes them to be. This may only be an arc 200 meters wide or it may be a full 360 degrees around his position. The tendency to focus only to the front is a bad idea. Hard-Target Interdiction teams have at least four personnel on them. Until it is time to engage targets, at least one of these members should be observing and performing hasty and detailed searches to the flanks and rear of the team. Due to the high-risk nature of HTI missions, the threat could and likely is going to come from any direction.

Sketch the terrain so that notes can be taken on major visual references. The observer records any anomalies in the terrain he sees. Note the light conditions, as these create shadows that change the picture



completely as time passes. Periodically, the team must repeat the hasty search followed by a detailed search of the area around the team. At times, the team may arrive and occupy an Objective Rally Point a couple of days prior to occupying the Final Firing Position. Their searches begin from the ORP and may move to different positions around the ORP. Teams should keep movement down as much as possible though, do not risk leaving ground sign to move around and observe the area too much.

Why Objects Are Seen

How the observer sees an object that attracts his eyes is based on several factors. These are the same factors that apply to the principles of concealment, but they are now used to detect enemy presence or threat instead of using them to guide you in camouflage and concealment techniques.

Shape

Many items that enemy forces wear can be instantly recognized. The AK-47 is an excellent example of nearly global recognition by its shape. Experience and exposure teaches people to recognize items by their shape. Exposure to the critical shapes that may be recognized as enemy equipment keys observers in to looking for these shapes and their recognition as associated items of threat interest. Geometric shapes also stand out. Nothing in nature is a straight line. In a field of vision that is the battlefield, a straight line such as a rifle barrel or an antenna will stand out.

Shadow

A major reason that observers sketch or photograph their area of observation is to detect the presence of threat objects. As the light conditions change, items may be revealed to the observer because a shadow was created by that object. The object itself may be completely unidentifiable to the observer, but the shadow may tell the rest of the story. Many times personnel in the field are not aware of the sun's effect behind them. Close Quarters Battle operators frequently will look for the shadow of a threat as it approaches down a hallway. These are all target indicators. When an observer sees an abnormal shadow, he is going to have to look into that shadow to see what the object is. A method for doing this is to make a paper cone that the observer slips over the objective lens of the scope. This narrows the amount of ambient light entering the lens. This has the effect of eliminating too much light which overwhelms the dark area of the shadow.

Silhouette

Silhouette is caused essentially by two things happening as far as an observer is concerned. Objects are silhouetted when they stand or are against the skyline. This can occur during the day or at night. The other occasion an item is silhouetted is when a sniper, for example, bobs his head up. He is likely going to cause a shadow that is in front of, or behind that sniper. Silhouette is also caused by miscoloring camouflage and causing contrast with the background.

Surface

The surface texture of an object is important to how easily that object is revealed to an observer. As was mentioned in the section on camouflage, merely painting an object may not conceal it. If the background behind an object is "busy" and the object itself is smooth, it is easily detected. This is why burlap garnish is so effective in making an object difficult to detect.

Spacing

The spacing of objects is a low level indicator. It takes a trained eye to detect a repeating pattern of camouflage. This image is an example of a repeating camouflage pattern. The following photo shows an HTI shooter camouflaged with artificial plants. Note the repeating pattern of camouflage to cover the gun barrel

on a diagonal line across the position. The 11th Armored Cavalry Regiment used an experimental camouflage pattern on their armored vehicles in the late 1970s. It was contrary to the standard pattern flowing method of applying the paint that was in use then and today. The patterns were randomly placed on the vehicles and there was no black. The borders of the different colors were in block lines instead of a flowing line. This created a very irregular outline. The pattern was much more efficient on the Reforger exercise according to observers. A year later it was removed and never seen again. That pattern defeated surface and spacing problems associated with current camouflage patterns on vehicles.

Siting

Hidden enemy positions may be poorly sited. Machine gun positions are placed on dominating pieces of terrain to cover avenues of approach and to protect defensive positions.

Because they are placed on these dominating locations, it is easier to locate them. Crew served weapons have a larger "visual footprint."

Siting and movement are major indicators for detecting the presence of crew served weapons.

Color

The color of an object is one of the biggest reasons an object is detected. These are stationary objects, of course. Such gross errors as using the wrong color indicate the level of professionalism or proficiency in an enemy force. Color is one of the first fundamentals of camouflage. If an observer is directed to a stationary object because the color stood out, he is likely to encounter a lesser-trained adversary.

Movement

Movement is the No. 1 enemy of staying concealed and it is the highest ally in the detection of them. An enemy position may be perfectly camouflaged and sited. A branch kicked by someone in that hole instantly attract the attention of an observer.



Elements of Observation

There are four elements of observation. These elements may occur simultaneously or at different times. These factors all depend on some physiological and physical restrictions. Those physiological and physical factors are sometimes determined by weather conditions, degree of fatigue, diet and amount of stress incurred up to that point in the mission. These four elements are:

Awareness

The awareness of an observer is in relation to the events that are occurring around the team. There are a few factors that affect the level of awareness of a team during all phases of an operation.

- An object's size and shape can be misinterpreted if viewed incompletely or inaccurately.
- Distractions can occur during observation that affect the level of awareness and can cause objects to be missed or misinterpreted.
- Active participation or degree of interest can diminish toward the event. This is a major problem with special reconnaissance teams that observe a target area for up to 14 days at a time. The observation takes place, but quality collection diminishes from the first day on. The more routine the mission becomes the lower the quality of the product. And the more dangerous it becomes for the security of the team.
- Physical abilities (the five senses) can be limited.
- Environmental change can affect or occur at the time of observation. When it is cold and miserable outside the time behind the glass becomes more miserable. Interest in performance of the mission degrades with the poor weather.
- Imagination or perception can cause possible exaggerations or inaccuracies when reporting or recalling facts.

Understanding

Understanding what an observer is seeing is based on training, experience and practice. By far the greatest factor here is experience. Nothing short of time behind the scope will make a good and accurate observer. An observer must also have the technical knowledge to be able to interpret what he is seeing.

Recording

Recording is keeping a record of what is seen, heard, experienced, and passed on. It takes the form of written logs, photographs, sketches, tape recordings, and any other media that records information. Accurate record keeping is important to the observer for many reasons. Observation logs are information that later becomes intelligence once it is analyzed and processed. Nothing substitutes human eyes on a target or enemy. The level of detail that goes into recording is based on several factors.

- The amount of training and practice in observation.
- How skillful the observers are based on their experience.
- Similarity with previous events, deepening their experience level.
- Time interval between observing and recording.
- The ability to convey or understand information oral or other forms of communication.

Response

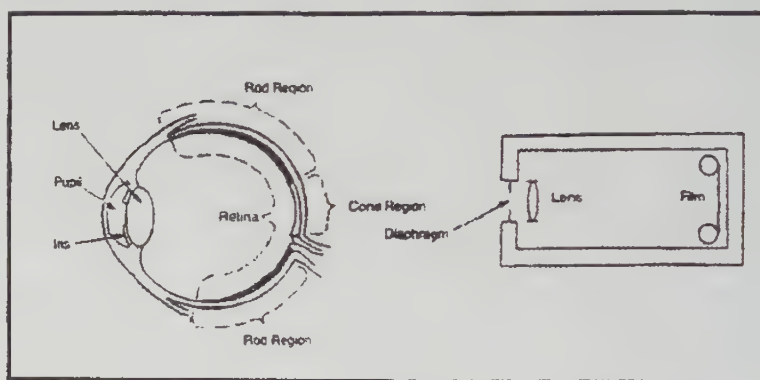
The response is the sniper team's reaction to what they observe. This may be recording the information, transmitting the data out, taking a shot, or running like hell.

PRINCIPLES OF VISION

The principles of vision are those physiological actions within the eye. It is good for an observer to know

the eye's capabilities and limitations. The eye works much the same way that a camera lens works. The eye has a lens that focuses much faster and more precisely than a good camera lens. The iris regulates the amount of light that passes through it much the same way a diaphragm does in a camera lens. The iris allows the individual to see in bright light by closing and cutting down the amount of light traveling into the eye. It opens in dark areas, thus allowing more light into the eye. The eye can do one or the other and most of the time the amount of light going into the eye is a compromise of the best and the worst conditions. The eye's "camera film" are the photo-receptor cells located on the back of the eye (retina). There are two types of cells in the eye:

- Cone Cells. These are located in the center area of the eye. They are the cells used for daylight vision. These cells enable you to distinguish color, shape, and sharp contrast. The eye needs a lot of light to activate the cone cells. These cells are blind during periods of low light.
- Rod Cells. The rod cells are always active and surround the cone cells. The rod cells produce a substance called "visual purple." As the light level decreases, "visual purple" is increased, thus allowing the rod cells to be more efficient at registering light. Turn the lights on, however, and visual purple is destroyed. It takes time to build this back up. This is commonly referred to as "getting your night vision back." The rod cells are those cells that are very sensitive to movement. Because they are located at the periphery of the eye, detection of movement is best attained when seeing the moving object "out of the corner of the eye."



Limited Visibility Techniques

As light sources dim, the eyes automatically compensate. As less and less light is available the cone cells shut down because they need a lot of light to function correctly. The rod cells begin to produce visual purple and night vision capabilities come into play. Another effect which is the same as the camera is that when the iris opens up, the eye has to focus more often for objects of different distances. This constant refocusing causes the eye to fatigue faster. For many people the end of the day and the sun going down is a time to relax. It is sometimes so ingrained into a society that normally alert soldiers may succumb to this ingrained habit. An alert observer may pick up activities when enemy soldiers "slack off" and make mistakes. The sniper team must be alert not to make the same mistake.

While there is little scientific evidence to support it, one method that seems to work is that the eye and other senses become keener when the individual is hungry. This seems to have its roots in our natural instinct for survival. Based on this, the sniper team should avoid eating their evening meals until well after stand-to and into the dark. This also works to a degree on the ability to shoot. It may be the result of keener vision from a little hunger and therefore better sight alignment and sight picture. Limited visibility is from low light to absolute no light. There are three principles of using night vision to its best effectiveness:

- Night Adaptation. Allow 30 minutes for the eyes to adjust from exposure to bright light to obtain good night vision capability.
- Use Off Center Vision. Never look directly at the object you are trying to detect. Rely on the peripheral

vision. Let your eyeball float off to one side or the other of the intended object. Your rod cells will detect the object better. Avoid the tendency to look directly at the object when you do see it with the rod cells.

- Scanning. It is important that the eye is stationary to see objects well. While you are not looking directly at the object, the eye must be stationary to detect objects.

The observer must be aware of the things that degrade night vision capability.

- Lack of Vitamin A.
- Colds, headache, fatigue, narcotics, alcohol and heavy smoking.
- Exposure to bright light.

Darkness removes the detail seen in an object. The observer must be trained to recognize objects by their outline alone. Some methods to improve their night vision include:

- At night go outside and practice looking at objects that you are familiar with. Concentrate on using the rod cells only. You know what the object looks like in the daylight. As you do this more and more you should be able to note an increase in the amount of detail you intake. Diet is especially helpful in this. Vitamin supplements enhance this ability to a degree.
- Open the iris. The eye can be trained to open the iris even more than normal. This is done by exposing the eye to more low light situations and exercising night vision use more often.
- Practice silhouetting objects against a brighter background.
- Try to maneuver to place an object to be seen between a light source—no matter how small—and the eye. This silhouettes the object and allows a little more light into the eye.
- Lower the body to the ground. This changes the perspective angle of light into the eye. This also tends to backlight objects against the sky and whatever light is out there. When you are close to the ground, observing with the head canted will work better as the rod cells at the sides of the cone cells are more numerous than those above and below.

HIDE SITES IN HARD-TARGET INTERDICTION

Hide sites have long been a fundamental of the sniper's mission. The U.S. Army's Special Forces, Special Reconnaissance mission formats also use hide sites to perform their long range stand-off observation missions. Methods of hide construction have long been studied by various special operations and the long range surveillance units (LRSU) in the U.S. and other military forces. One of the major essential factors is in speed of construction. A team must locate and recon their site, begin construction, haul in materials, complete construction and camouflage within one dark period. For a two man sniper team this task is formidable. For a four-man hard-target team it is a little less difficult but not much. The four-man element may lay in one hide or it may do two hides with the sites interconnected by wire or radio communications.

There are already many sources of information on the different types of hide sites, their planning, site checklists, their disadvantages and advantages. *TC 31-20-4* is an excellent source for the construction of layout of sniper hides. There are some differences in the construction of hides that should be considered. These are mainly because the big guns all have muzzle brakes that require some special consideration in the hide.

Considerations for the Construction of the Hide Site

The pre-mission planning process is where the team begins to assess the type of hide it intends to construct. Special Operations sniper missions usually dictate that a team arrive in the target area up to three days prior to the intended shot. This is because SF teams always do area assessments of the area they go into

from the second they hit the ground. Area assessments are part of the intelligence gathering process. This information is intended to expand the picture of the enemy situation on a strategic level. By their nature, deep penetration sniper missions are also special reconnaissance missions. Burst transmission satellite radios and burst transmissions High Frequency radio sets allow this information to be passed nearly real time, although teams object strongly to such a high volume of radio traffic. This requirement is usually because commanders want priority intelligence requirements within 15 minutes of their actual observation.

Hide sites are always constructed during periods of limited visibility. The main reason for this is because the site will have a direct line of sight to the target. To be seen and shot at, the target must also be able to see the sniper team in action. A very low profile must be maintained while constructing the hide site. The duration of the mission on the ground does not really affect the basic considerations in the construction of the hide site. These are the same for standard sniper missions as well as Hard-Target Interdiction missions.

Location

- Location is super critical. Factors in location include the ability for the site to blend with the flow of the terrain, enough surface disruption to allow for the soil dug up to be buried a short distance away from the hide site without altering the terrain, ease in the digging process by using softer soil, away from natural lines of drift, away from natural points for registration of indirect fire weapons, and away from animal trails.
- The enemy location and capability is a consideration. Do they patrol as a part of an anti-sniper plan? Do they have thermal imagery or passive night vision systems? Does imagery show evidence of flare support? Is there a reaction force? What is its reaction time? Does activity around the target site tend to be noisy enough to mask team hide site construction.
- Can the team site a mission support site that allows operators to switch off while in the hide site? This is sometimes an option when the mission is a special reconnaissance mission to be followed up with a sniper mission in the event a series of predetermined events occur.

Time

- The amount of time the team is expected to be on the ground will determine the type of hide to be constructed. A late afternoon insertion followed by an early morning shot may not require a hide site at all. A reconnaissance mission with a duration of 10 days followed by a sniper mission dictates a semi-permanent hide site that will probably take all night to construct.
- The time needed to construct the hide site. It is possible that the team runs out of time. You must plan to camouflage the site in its current stage of construction if the hide is not done. You never know what may happen. At 2 a.m., a patrol may pull in and set for a couple of hours, bringing construction to a halt. In a couple of hours the sun is going to start to come up. The team must camouflage their site and plan to finish it again during the next period of darkness. In this case, surveillance must be placed on the unfinished site for two reasons. First, to call a compromise if the hide site is discovered by enemy forces. Second, to additionally camouflage the site if the job wasn't done well enough in the dark. This is a risky but necessary move.

Personnel and Equipment

- Special equipment needed for the construction may consist of saws, D-handle shovels, picks, garden trowels, chicken wire, artificial overhead supports, 550 cord, steel wire, stakes, etc. Hide site construction rehearsal will identify the special equipment needed for the site. A full size hide need not be built (for the rehearsals) as is the tendency. A one-quarter size hide is sufficient enough considering how time is always at a premium. This will identify any problems and specialized tools needed for construction.
- Heavy guns with vented muzzle brakes require special venting of the muzzle brakes to keep down the blast

in the hide site. One of the best materials for this is the flexible hosing (4 to 6 inch diameter) used for drainage in house construction. This material is light but somewhat bulky. The muzzle brake MUST be vented to the outside of the hide. More details later in the chapter.

- When using natural materials for construction of the hide site the team can do a couple of things. They can collect these materials (logs for overhead support, 2-6 inch diameter) as they move and camouflage the evidence. This means the team will not have to move back over the same terrain to gather materials for the construction. This is an on-the-spot decision based on the enemy threat and the team's ability to carry the additional load on top of their already considerable load.
- Personnel needed for construction. A four-man sniper team usually has the capability to construct a hide in one period of night. The terrain and number of actual hides will actually dictate. In a special forces unit, the A detachment can be used to support the hard-target effort. The entire team may construct and pull security. The shooters occupy the hide(s) while the rest of the team covers their rear from a mission support site or overwatch positions.

The Steps in Hide Site Construction

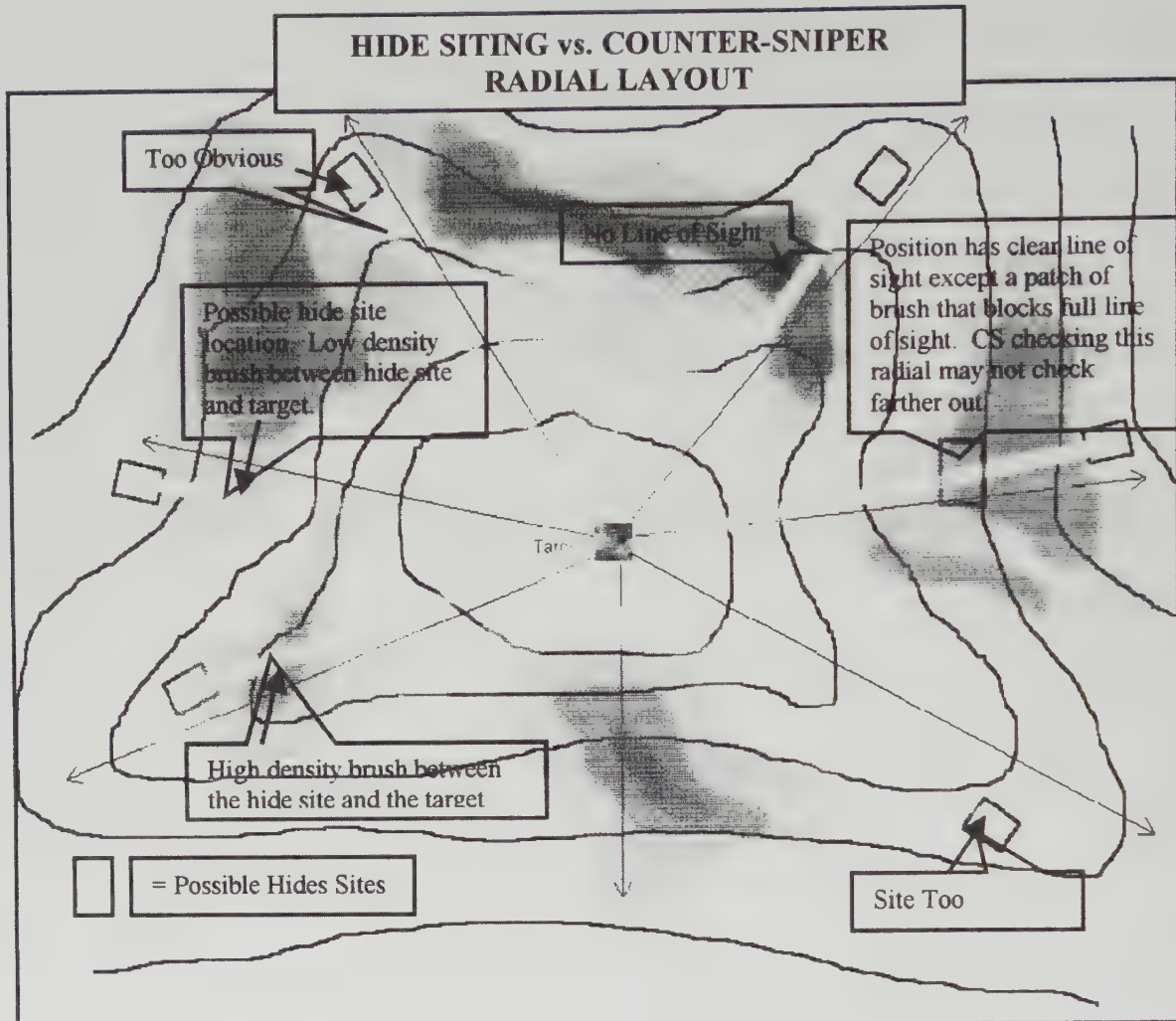
The construction of any hide site is complete in six phases. These are:

1. Reconnaissance phase
2. Surveillance phase
3. Preparation phase
4. Construction phase
5. Occupation phase
6. Shut Down phase

The *reconnaissance phase* is the part of the mission where the team pulls into the Objective Rally Point and launches a recon team to fix a hide site(s) for the mission. The team should sit in the ORP long enough to determine the threat situation in the area. In past training missions teams have been mandated time lines that have them on the ground and in a hide site in less than 18 hours after infiltration. This is totally unrealistic. From infiltration (depending on the foot movement distance) the time from occupation of the ORP to being active in the hide site may be as much as 48 hours. Recon phase includes not only fixing a hide site, but finding any natural support materials for that hide site. Proposed sites from mission planning are either confirmed or denied and other sites are nominated as necessary. The recon teams return to the ORP and disseminate information. The team leader decides on the location of the hide(s). Some pointers on hide site selection:

- Be aware of the position of any backlighting that may silhouette the hide site. Look at the position of the site from an enemy's perspective. Do this at standing, kneeling and at ground level.
- When siting the position in, you are going to check for clear lines of sight to the target area. Look at your position from a counter/anti-sniper operator's point of view. He is going to follow along the terrain contours starting close in and walking around the target. He will work in ever-increasing circles looking for clear lines of sight, much the same way the sniper team did for selecting their sniper position. He is going to eliminate areas that he does not need to walk because of time and other reasons. The sniper team can intentionally leave some visual interference between the gun and the target. In doing this, any countersniper operator will hopefully see this lack of line of sight and figure that checking any further out on that particular radial isn't necessary.

The *surveillance phase* is where members of the team pull a surveillance of the proposed hide site locations.



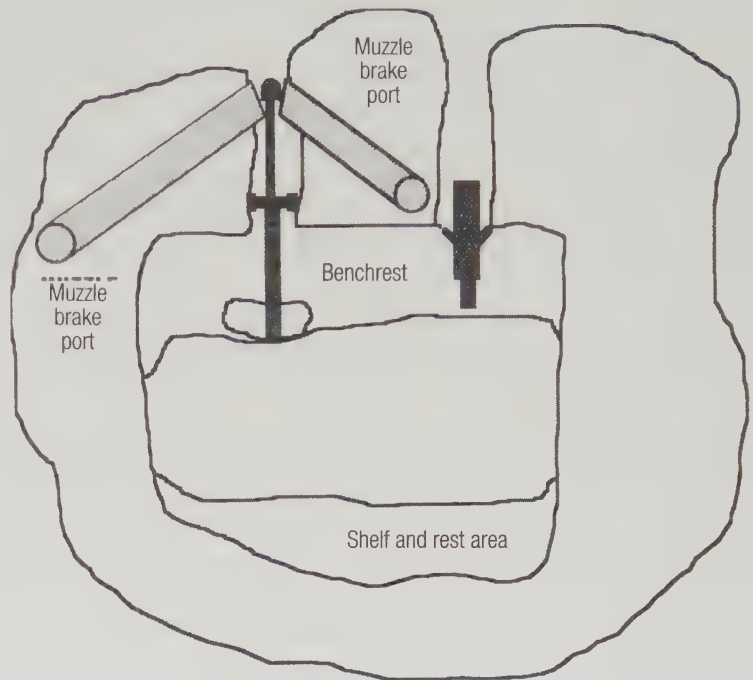
The duration of this surveillance depends on any signs of activity that the team finds in the area. If there is absolutely no evidence of human activity in the area, the surveillance may only last 6 hours or so. If there is evidence of activity, civilian or military, the surveillance should last an entire day period and maybe a period of darkness before hide site construction can begin. The team must confirm or deny that patrols or civilian traffic does not regularly move through the area. There is nothing that can be done for the one time chance a patrol or civilian moves through. The team relies on its stealth and camouflage to defeat detection in this event.

The *preparation phase* is when the team gathers its natural materials (if needed) to construct the hide site. This is based on the recon of the hide sites and the final determination of the type of construction to be used. The gathering of small diameter logs for roof material can go on at the same time the surveillance is being conducted. Even if the proposed hide(s) are no good, these materials can be used in other hide sites. Tools needed are prepped and those that are not needed will be cached. They may or may not be recovered for exfiltration.

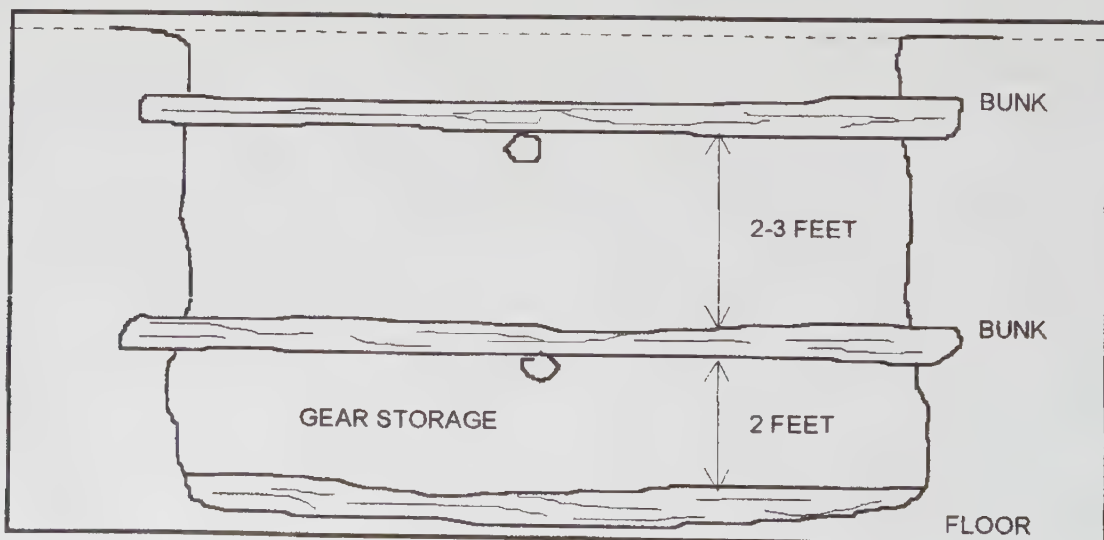
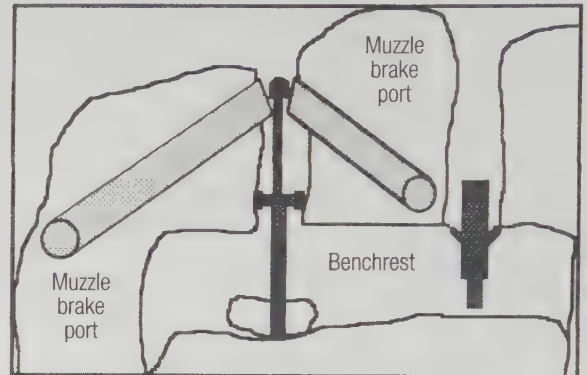
The *construction phase* begins as soon as possible once the sites are confirmed. This will be under the cover of darkness. The team upgrades their personal camouflage and moves into the proposed hide site location. This phase may take more than one night period and provisions must be made for the rapid camouflage of the site in the event the team has to depart and complete the construction the next night, or whenever that may be. During this phase, security precautions are easily tossed to the winds as

focus is on completion of the hide site. As in patrolling, never sacrifice speed for security, unless you have the guns and backup to do that. Sniper teams do not. The construction begins and proceeds as follows:

1. Post security. Security for high risk missions may require anything from the norm or placing a man or two in dominating positions to overwatch the team to tripwire boobytrapping trails that would inevitably result in the teams being caught and engaged. Sometimes the best early warning is the destruction of some of the enemy forces that are going to do the compromising.
2. Remove the Topsoil. The removal of topsoil must be most carefully done. One practice is to lay out ponchos or other light ground mats and as the topsoil and grass is removed, it is placed on these mats exactly as it is removed. Think of the process of digging the hide as removing different layers of material. They then all are replaced in the reverse order they are removed. The topsoil will contain the grass, plants and weeds of the area. If the hide is at all above the previous ground layer, additional top soil will need to be excavated and moved to the hide site. Take great care (and that's tough at night) not to allow any soil to spill over onto the ground. Also be wary of placing the ground sheets on sensitive grasses or plants, as this will be over-compressed by the weight of the earth and may not recover.
3. Dig the hide site pit. Once the important top soil is removed and the outline of the actual hole is laid in, the age old practice of digging begins. The depth and width of the pit depends on mission duration, number of men in the pit, and any creature comforts that you want. Disposing of the dirt from the pit is the most difficult part of digging it. Clearly it cannot be just dumped on the ground. A major problem for a team carrying earth away is leaving sign of that activity. There are a few options for dealing with the disposal of pit earth:
 - Some of the earth will be used to make the above ground level berms around the hide. The earth is spread around the hide to blend the profile in more with the ground in the area—essentially making a natural-looking modification to the terrain. The top soil under this must be removed too. This earth is also used to lay in the observation and shooting ports and for the burying of the vent tubes for the muzzle brakes on the guns. This is a highly recommended method as there is much less travel required to dump extra dirt. This area can be 4 to 6 times the size of the pit in square footage.
 - Place the earth in empty rucksacks and carry away to a less likely traveled area, dump it in a depression and then camouflage it.
 - Locate a depression close to the hide side that, when filled in, will still match the flow of the terrain in the area. Removed the top soil of that patch of ground. Fill the depression and replace the topsoil materials.



- If the terrain is steep and rugged (like in Korea) you may be able to find areas of natural slides. The same soil that you are dumping is likely to be the same soil that is exposed below the topsoil after a slide. You can dump the soil into this natural slide spot, usually without time consuming camouflaging of that dump site.
- DO NOT dump earth into a cut or dry creek bed. Changing the land profile in these areas will immediately be noticed. The lay of creekbeds and cuts is determined by water that flows through them, even if the cut has only intermittently flowing water. A high spot, even well camouflaged would stand out. If you were unlucky enough to have a rain after dumping the earth in this spot, the water would either cut a path through it, or the water would build up behind it. In either case, if an enemy force sees it, they will know something is up.
- Loophole construction: Loopholes are the ports that the shooters fire through from within the hide. They are also the ports that an observer uses to look out of the hide with the spotting scope. Special consideration must be given to hide sites with muzzle brake guns. If the muzzle of the gun is outside of the position and the brake is a side-venting type (Barrett, AMAC, M600, etc.) the first shot will cause total disruption of the camouflage. If the hide is well camouflaged with natural vegetation the blast will cause a huge visual target indicator to enemy observers. The same is true for vertical-ported muzzle brakes. There is a solution to this problem. By using flexible hosing, the kind commonly used for drainage in house construction, a sniper team can pull the muzzle of the gun inside of the loophole and conceal the blast of the gun. When the berm or parapet is constructed with earth from the pit, these vents are layered in so that the muzzle brake is directed into these ports. The ports are then vented to the sides or up and away. Consider the vegetation over the hide site when directing these vents. Have the end of the vent tube about 2 inches from the muzzle brake and nearly all of the gasses will be captured by the tubes. The loopholes themselves can be lined with flexible round tubing or some other artificial form of support. Three wraps of chicken wire will hold up a fair amount of earth and it's lightweight and compressible for transportation. Depending on the type of soil and amount of overhead weight on the wire, you may need more wraps or reinforce the tube with some sticks.



- The Benchrest. The benchrest is the place where the toe of the rifle lays on a sandbag and the observer sets his spotting scope. Data books, calculators, and targeting material can go here also. As you can see in the drawing the distance from the back of the benchrest to the end of the barrel is long. The end of the muzzle is recessed about a foot inside of the loophole. You can get an idea of about how much ground these hide sites cover. There really are not much different from a semi-permanent hide for conventional sniping when you have to spread the cover on the hide out to blend it with the terrain. The benchrest can also be constructed out of 2 to 3-inch diameter logs when the soil isn't strong enough to handle that type of construction design. Once the pit is dug, the operators dig along the sides of the pit to lower the level of the benchrest below ground level. The logs are laid in, and the ends are covered when the parapets are built with the pit earth.
 - A Bed or Resting Deck. A deck to rest or sleep on is a must for mission durations over three or four days. There are a couple of different techniques for making beds inside hide sites. If there are more than two operators in the hide site, you can make bunk beds in the back of the hide. Cut 2- or 3-inch diameter logs and lay them in the same way as described in the part on benchrests. One deck is about 2 feet off the floor and the second one is about a foot below ground level.
 - Drainage System. In environments where there is the threat of rain a drainage system is needed. In the bottom of the pit, dig a couple of sumps about a foot in diameter by two to three feet deep. Fill these with rocks to slow the flow of water to the bottom. This keeps the water from flooding the sumps too fast. The floor of the hide can be laid in with 2- or 3-inch diameter logs and then covered with light brush if such a plant is in the area. Waterproofing the roof is a good way to keep out ground water. But that will not do the entire job. If you are unfortunate enough to have your hide in a place with a high water table there are a couple of solutions. An air shipping pallet cover can be carried in and used to line the hole. This also keeps the hide warmer.
4. Construct an Overhead Cover. Overhead cover ranges from a roof that is resistant to light indirect fire (mortars and grenades) to a simple structure of branches and wire that is camouflaged to the area. Hasty hides that can be built in a couple of hours usually are made in a depression. The "roof" structure is made of a couple of center posts with a weaving of branches. This is then covered with leaves, vines, pine bough, or anything that naturally lays on the surface. In the desert, an aluminum support structure is covered with a painted tarp that blends to that area. Then sand or other local material is added to the camouflage. The type and construction of the overhead cover is dependent on a few factors.
- Enemy threat from direct and indirect fire. For special operations missions, this usually isn't a consideration because of the depth of the mission. That's not to say it isn't done, it's just not the most important consideration. The threat always exists from direct fire, but there usually isn't the resources that a conventional sniper team may have for heavy cover.
 - Need for overhead cover to support human weight. It was mentioned earlier that there are some places that a hide may be constructed that also have the possibility of foot traffic on them. In Korea, the many ridgelines are also trails because off the ridgelines, the terrain is so steep that you can't do anything but fall down it. When a hide must be constructed on or near a trail, the roof must support human weight and the rest of the hide construction is dependent on the location of that trail. It is possible to camouflage that trail's existence at both ends hoping that anyone that walks along it will think the trail ended. Everyday local traffic will only suspect something is going on then. Hides have successfully been constructed that saw daily foot traffic directly over the center of the roof without compromise. Very dangerous, no doubt, but sometimes necessary.
 - Availability of natural materials for overhead cover. The availability of medium diameter logs in the area will dictate whether the team can put in "hard" overhead cover. The team can't carry that stuff in because

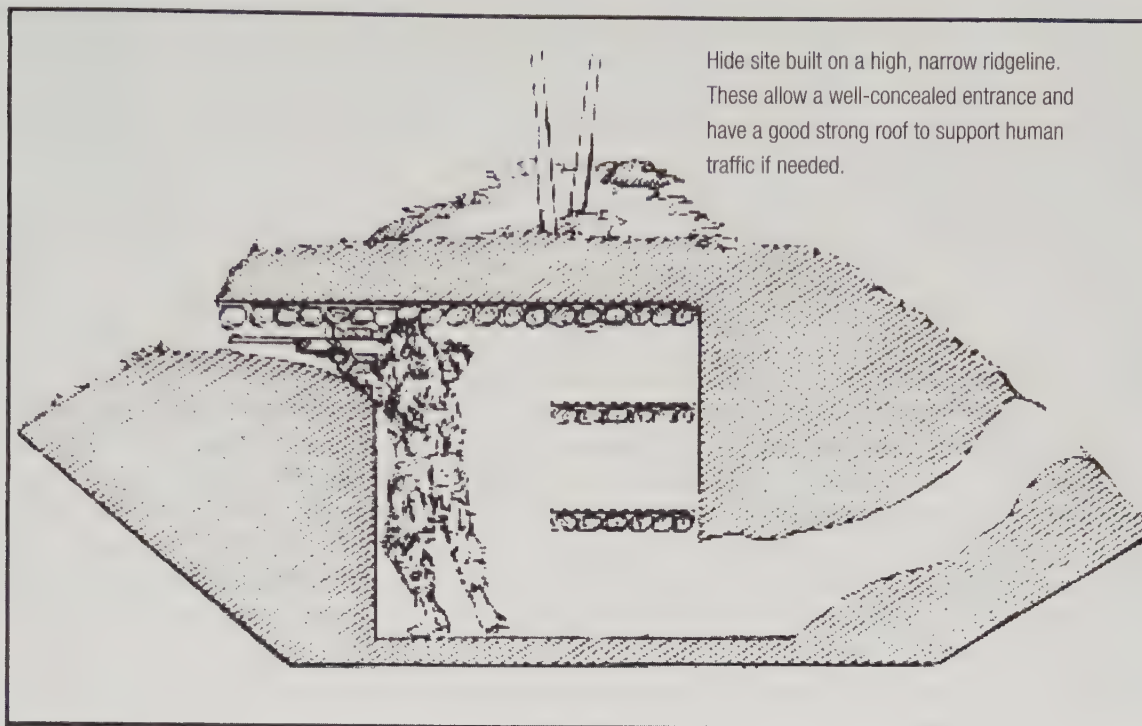
of the bulk and weight. Sand bags are an option, but then it takes serious logs to support the weight of the sand bags. Sometimes aluminum poles can be carried in and used to support a heavy roof. Bottom line though, if it isn't in the target area, you can't do "hardened" overhead cover.

- **Enemy Detection Systems.** If the enemy has airborne FLIR or thermal imagery platforms the team must make the roof resistant to the transmission of heat signatures through the roof material. This is a layered process. First goes down the support structure. Then goes down a layer of mylar material to block the unnatural heat sources. Finally, the earth and live vegetation goes on top. Good detection systems can detect the difference between dead and living vegetation. A square patch of dead vegetation is a giveaway.

The major factor in constructing overhead cover is probably time. The more "hardened" a roof needs to be, the more time it will take. These types of hides may take more than one night period to complete. In that case, ready camouflage material must be on hand to camouflage the unfinished hide site until the team can return to finish the job.

5. **Construct an Entrance and Escape Routes.** Usually, you will only have one entrance. It will be facing away from the enemy. The terrain where the hide is built may allow for a little different twist on entrances and escapes however. Hides built on high ridge lines allow for hides that are strong and have excellent entrances and escapes. Having an escape that goes in the direction of the enemy isn't a bad idea either. Countersniper operators may approach the site from the rear hoping to seal off the team's escape. Having an escape to the front and the rear gives the team a much needed option. Slant the entrances downhill to provide drainage if possible. The roofs of these hides easily support human traffic and they are constructed by burrowing in. Log overhead cover isn't possible though when doing the burrowing method. Recreating a trail on the roof when you have dug down is also impossible, however. These hides require some skill and great care. Bad site selection could mean a weak roof. The hatches need to be as strong as the roof when it comes to supporting weight or resistance to fire. The "plug" should be made as small as possible to get the team and its gear into the hole. If possible have a 45 degree or tighter turn in the entrance. This gives the team some reaction time if compromised by ripping the door open. Enemy troops simply can't stick their gun in the hole and open fire to clear the team out.
6. **Camouflage the Hide.** A good camouflage job on a hide site mandates 100 percent natural camouflage. This part of the construction job will have to be final checked in daylight conditions. If the team is split, then one operator can check the other's team and so on. It takes a good objective view from someone who didn't construct the site to see the anomalies that may stand out to enemy observers. All of the top soil material that was carefully removed and set to the side gets replaced. One trick is to spray Miracle Grow beneath the top soil layer. Once the topsoil is down, you can carefully transplant vegetation to enhance the hide site, but don't overdo it. Once completed, retreat the area with Miracle Grow. Remember that sophisticated infrared detection systems can tell the difference between living and dead vegetation.
7. **Continuously Upgrade the Camouflage.** As the tactical situation allows, operators must update their natural camouflage. If the topsoil and implanted vegetation takes, this job will go much easier. It becomes self maintaining. You will know by the afternoon of the next day if the vegetation is dying and must be replaced. Have a plan in place to take care of this if needed.

Actions in the Hide Site. These are things that the team does in their hide site on a scheduled day to day basis. These are things like security of the site, camouflage discipline, weapons maintenance, health maintenance, updating range cards and data on the guns, chow schedule, watch rotation, maintaining commo schedules and other activities. The team should rehearse the emergency egress drills and the actions to be accomplished by each team member in the team if they must egress. The latrine procedures must be worked out—is the team going to go to the bathroom in bags and then carry them out later, or do they leave the hide at night to go to the latrine.



Hide site construction is not just hole digging, covering the top over and throwing on some leaves and sticks. A good hide site starts with mission planning and using all intelligence sources to locate a prospective "area" for a hide. Planning an eight digit grid of a six-foot square on a 1:50,000 scale map is a waste of valuable time. Using your selection considerations, plan the type of hide you want and pick some prospective areas. Go in and confirm or deny these "areas," then select the best place for a hide site. Careful and slow reconnaissance will help in mission success and more importantly survival.

Communications requirements present some special problems. For the conventional army sniper, they have to camouflage a long whip antenna sticking up out of the hide. Huge problem. For special operations snipers, a SATCOM antenna or a High Frequency long wire antenna presents even bigger problems. The communications requirements for special ops teams are usually unreasonable and triple redundant. An SF team's load is usually 30 percent commo gear by total weight. That's a huge percentage of the burden. Commanders want to be able to talk to their teams in the field NOW, even though they can't do anything to influence the situation that may be thousands of miles away. One of the solutions to antenna problems is having a lot of coaxial cable.

A SATCOM antenna could be placed high in a tree or at a remote and difficult to reach location. The coax cable then is run back to the hide and buried, painted, camouflaged or whatever to conceal its presence. HF antennas are much larger. A long wire antenna may be as long as a hundred feet or more. Because of radio wave propagation restrictions these antennas have to be located at pre-determined heights off the ground or the bounced signal will not work right. An HF antenna may be located only a few feet off the ground. Leaving an HF antennae in place is a bad idea. The team will have to make an on-the-spot decision on how to best handle the HF problem. It is likely that the antenna will have to be laid out and then rolled up each time the team makes communications.

The *occupation phase* is that phase of the mission where the first rotation of the sniper team moves into the hide. A single team occupying a single hide has a more difficult time because they have no way to ensure that the camouflage on the trapdoor is good once they are in. Once the hide site is finished, a shooter with his rifle moves into the hide and makes a final line of sight to target check. Any visual blocks left in place as

countermeasures to a countersniper effort must be removed between the hide and the target. A team member must go downrange and remove these blocks. If the target is present in a fixed installation or field site, this should be done in a ghillie suit, fully camouflaged. The sniper covers him from the best location possible. If this is a sniper ambush, and the intended targets are not in place, this is more of a patrolling matter. A shooter still remains in place to cover and verify that visual blocks are down.

The hide site may be of limited size because of time and construction constraints. A four man hide site is large and two hides sites for two men each doesn't save on time of construction at all. If anything, constructing two smaller hides takes longer. Security is a main reason for this. Two sites will have to be spread out to avoid crowding an area. To cut down on requirements for non-essential equipment storage in the hide, you can cache the bulkier non-essential gear in a position close to the hide. This only needs to be a few feet away. The team can quickly dig this in and do good camouflage to it to prevent it from being found by enemy forces.

When the team moves into the hide, one man should go in and pull the plug into place. The rest of the team remains outside to critique the fit and camouflage of the plug. This is the best hope of ensuring that the trapdoor will blend well with the rest of the hide. Any antennas that are out must be inspected for good camouflage. Team gear is pushed into the hide site and the rotation plan begins. Team members enact the collection plan, observation log, fill in data for their range card or photograph and the daily routine begins until the shots on target are taken. Prior to taking a shot during the expected time frame, antennas should be taken down and packaged for rapid movement from the area if need be once the shots are taken.

The *shut down phase*. Once the primary mission is complete, the team must depart the hide and leave the area. This departure depends on how the team planned their exit. It ranges anywhere from a rapid departure after taking the shot and leaving the hide in place, to waiting out the situation and quietly departing at night and recamouflaging the hide site, leaving it in place forever. Generally, it is recommended that the team wait out the situation and leave the hide at night. Hopefully, the shots are taken as late in the day as possible. This means that their time in place is shorter. Depending on the target, enemy forces may not pursue a search for the shooters. The team must completely sterilize the inside of the hide of any non-indigenous materials. Trash must be taken out. Scavengers that smell the garbage will shred the hide to get into it and the food left behind. They may try to get in just because of the odors left from eating food. CS powder liberally doused throughout the old hide is a good deterrent to scavenger invasion. Once all members are out of the hide, carefully recamouflage the area. Try to eliminate all traces of the team's presence.

This chapter covered a lot of information. It was not intended to contradict or repeat other sources of information already in existence in the sniper community. As far as equipment is concerned, remember what you put down, you may never be able to pick up again. Never leave behind emergency signal, medical, or food procurement equipment. The survival items that are listed for carry in the pockets are there so that you have them all the time. Certain items of high value and importance should have standardized locations in the uniform so that they can be rapidly recovered or used by other team members if necessary.

Camouflage discipline requires constant attention to detail throughout the entire mission. When using camouflage remember the target indicators that you can overlook or leave behind. They do NOT just consist of things that are seen. It begins at every level of the plan and the execution. Sanitize as much as you can anything that carries a strong odor. The irony of scent detection is that often the less sophisticated the enemy, the greater the capability of non-visual detection. Interviewed NVA and VC soldiers said that they could frequently smell U.S. forces when they were close by. Camouflage that falls off becomes a tactile and visual target indicator for the enemy.

Carefully consider the type of ghillie suit that you are going to use. Be careful to use the same suit for mission after mission. Traditional ghillie suits have their place but are bulky and heavy. The wearer pays a high price in dehydration and fatigue. A total uniform change in the field is also a bad idea.

Practice silent movement techniques frequently. Team members should take turns leading each other through silent movement courses during day, night and under foul weather conditions. Do it with all senses

functioning and then take those senses away one at a time as you re-negotiate the course. Work out standard operating procedures, hand and arm signals and any other methods of communication that are needed.

It is critical for sniper teams as well as all small units to maintain their proficiency in immediate action drills. These drills must be executed perfectly and viscously. Key to team survival rests on the execution of these drills. Sniper teams frequently operate without fire and air support. Their survival is in how fast they can break contact while inflicting as much damage as possible in as short a period of time as possible.

The teams' small unit tactics against detection devices should always be practiced and updated. Try new methods of infiltrating against all systems that are available. Stay up with current technology on countersniper systems that are coming online. Study countersniper techniques so that you know the adversary's methods of operation.

Countertracking drills have to be worked as efficiently as immediate action drills. Have passive and active countermeasures worked out as you patrol to your objective area. Once in that area, countertracking methods must be aggressively executed to keep trackers from detecting the snipers location and mission. To be effective in countertracking you must understand how a tracker works. If possible, attend a tracking course. If you cannot attend, practice tracking each other through progressively more difficult sign trails. Contact local law enforcement and arrange for their tracker dogs to work against you. The LE teams will jump at the chance to work with pros in their craft. They are as proud of their capabilities as snipers are of theirs.

Constructing a hide site for a heavy gun takes some practice. Yes, hides are hides, but working with a venting system and perfecting your technique must be done. Teams should practice on the range with the vent tubes to get used to them. They can be quickly laid in with sandbags and are actually a good way to keep down the dust and blast from the muzzle brake. By venting the gasses away from the gun, the observer can take up a more traditional position next to the shooter. Work out construction SOPs in the daylight and then execute them at night. The team should go out and practice siting hide sites and picking the best locations for them. Practice hasty hides that you can make in less than an hour or 30 minutes. Work out the special construction equipment needed and then make them more efficient for carry.

The field skills are the skills necessary to successfully infiltrate the area, execute the mission and survive the mission. Constantly practicing the procedures, immediate action drills and target actions until they are second nature is vital to mission success. You cannot rely simply on shooting skills and hope that the rest comes out in the wash. The field skills are fun to practice and the payoff is high.

FOOTNOTES

1. TC 31-20-4, *Special Operations Sniper Training and Employment*, Oct. 1996, pp. 4-16 through 4-17.
2. Author's addition to the text.
3. Extracted from TC 31-20-4, *Special Operations Sniper Training and Employment*, pp. 4-28.
4. Author's Note.
5. Author's Note.
6. All extracted from TC 31-20-4, *Special Operations Sniper Training and Employment*, pp. 4-21.



Target Analysis

Target Analysis is the process used to locate, isolate, and identify a specific target. The process not only locates and isolates the target, it helps identify the weaknesses that may expose that target to direct interdiction. The process applies to personnel targets as well as materiel targets. Target analysis is all of the analysis and planning that applies directly to the actions on the objective. The normal thought of actions on the objective has soldiers raiding a target or a reconnaissance mission of a specific target.

Hard-Target Interdiction against most targets is intended as a pre-emptive measure, as when tensions are rising between two or more countries. Hard-Target Interdiction teams infiltrate a target country to engage surface-to-surface missiles with suppressed .50-caliber rifles and monolithic bullets (to reduce impact signature). Because of the noise around the missile site, the impacts are not immediately observed. The teams get away clean and the missiles are rendered incapable of striking their intended targets. The engines may light, they may leave the pads, but they will not hit with precision.

This material is intended to introduce the reader/sniper to the methods of locating, identifying, fixing, and analyzing targets. Remember that the major subject of this book is anti-materiel interdiction. This means that a part of an entire complex may be identified for attack by a rifle shot. Many target complexes can be attacked by standoff (1,000 meters or more away) weapons, with the minimal collateral damage caused by a rifle shot. Before we get into the analysis process, we should understand some terminology and definitions associate with target analysis.

DEFINITIONS AND TERMINOLOGY

Targets. Anything of military, economic, political or psychological value that has been identified for an attack for the purposes of destruction, degradation, removal, or surveillance.

Target Systems. A network of major systems that include myriad targets within them that, when attacked, will delay or end the functional capability of the target system. Examples of target systems include: railway systems, fuel production, mass communications systems, or air transportation.

Target Sub-Systems. A major part of the target system. For example, within a target system of fuel

production, sub-systems include distribution networks, refineries, fuel terminals and different modes of physical transportation.

Target Complexes. Major complexes that are a part of a target system. Target complexes will have a number of individual targets within them in the same geographical location. For example, a refinery is a large target complex that is part of the target system of fuel production.

Target Components. Individual targets that may be attacked within the target complex. A component is any piece of machinery, structure or productive asset that contributes to the operation or output of the complex. When it applies to sniping human targets, the target component is the sole target and usually stands alone from the target system, sub-system, or complex. In an abstract way of looking at it, an enemy officer is a target component of the overall target complex of enemy personnel within an army.

CARVER Matrix. The CARVER matrix is a method used to identify a target for attack. It identifies a series of targets within a system, sub-system or a complex and rates those identified targets on six different categories.

- Criticality
- Accessibility
- Recoverability
- Vulnerability
- Effect on the Population
- Recognizability

Criticality. This rates how critical the selected component is to the system, sub-system or complex. At a strategic level, it rates the enemy's ability to wage war. For an HTI team, assessing the different components of a missile battery looking for the most critical and easily attacked target for the purpose of shutting down the battery is an example of criticality. A radar guidance van is super-critical to a surface-to-air missile battery ability to attack air targets. That van is very critical to the function of the entire missile site. The criticality of a target depends on several factors.

- Once the target is attacked, how much time will it take the effect to be felt on the target? This depends greatly on the method of attack. You may destroy a vehicle by adding different chemicals to the oil system. That takes a lot longer than blowing it up.
- What level of damage is desired on the target? Should it be completely destroyed or only taken out of action long enough for another event to take place. By completely destroying something, there may be a greater effect on the locals in the area, who may be otherwise sympathetic to the attacker's cause.
- If this particular target is removed, what is the possibility that other similar systems will be able to fill in the gap caused by destroying the target? An example is shooting the windscreens out of a single aircraft when there are three other aircraft sitting nearby that may allow an individual to escape.
- The number of targets and their function in the overall target system, sub-system or complex.

Accessibility. This applies a little differently to sniper interdiction than it does to normal attack by ground forces. Normally, a target is accessible when a unit of soldiers can enter the facility and gain access to that target. For an HTI team, accessibility may mean asking if the target is within their guns' range from the nearest position that allows the team to enter and exit safely and without detection. This is going to depend greatly on MET and ENV conditions in the target area. Those conditions will determine if the team is going to have to be closer or can be farther away to take the shots necessary. The bad news is that there may be countermeasures that can be detected or determined until the team takes a shot. For countersniper considerations to accessibility, the following CS measures will affect this factor:

- Enemy patrols that roam out to 2 Km around the target area.

- Fine wire mesh fences around the target that are high enough to cause a bullet strike on an incoming shot. This is rarely considered, but there is fence material that is specifically designed to disrupt bullets in flight to the area.
- The use of laser detectors to detect laser range finders and laser target designators. The surface material of a target can be made to be resistant to being lased by a range finder.
- High wall physical barriers that will interdict long-range rifle fire.
- Known sniper detection systems such as the Rafael that can detect a bullet in-flight and identify the location of the sniper team.

Recoverability. Once you interdict the specified target, how long will it take to replace that system, if it can be replaced at all? When recoverability concerns sniper operations against human targets, the recoverability of that target is usually determined at much higher levels than a sniper team may ever know. In the sense of anti-materiel interdiction, targets that can be engaged by rifles usually are targets that have a shorter recoverability time. This means that their designated “down time” has to be shorter. Some systems can be taken out completely by rifle fire (missiles and fuel systems, etc.). The required down time is a major determining factor in consideration the Recoverability of a target.

Vulnerability. This is the element of the attack that determines how vulnerable the target is to rifle fire attack. Is the target armored? Do the rounds fired from the .50-caliber rifle have the energy to penetrate the target? Do they have the sufficient power to damage the target once it is penetrated? Based on the down-time requirements, does the team have the sufficient firepower to take down the target?

Effect on the population. Television is one of the greatest means that we can use to understand the effect on populations of military activities around them. Right now, as this is written, NATO is bombing targets in former Yugoslavia. The effect on the population is shown live. People are fleeing the activities and the possible aftershocks of those activities. Missions that are carried out by HTI teams are going to have little or no collateral damage. Because of their high precision and the fact that they are not bombs or missiles dictate that huge residual effects are going to be nil. That may not always be the case. Each target’s attack potential must have this factor weighed in. Some other questions that may present themselves are: Are terrorist reprisals possible (as in the U.S. Embassy bombings in Africa)? What will be the allied nations’ reaction to a pre-emptive attack? Many of these questions are at higher than operator level, but for their survival, these should be considered in case the local population may have to be relied on to help in the case of evasion.

There is one more factor that makes sense for the low damage-causing, precision fire of long range rifles over bombs and missiles. An HTI team infiltrates a country to remove an anti-aircraft missile battery that will be able to engage U.S. aircraft on their way to eliminate a greater threat. This battery is in a country whose reaction to having their site bombed out of existence by a AGM-84 HARM missile cannot be determined (read: won’t tolerate loss of lives of their citizens). Since that country probably won’t react to having a radar being shot to pieces, a pre-emptive strike that does not eliminate personnel is much less likely to cause an international incident. Some countries will keep a low profile when they lose some hardware, but kill off 30 people in the process and that raises the ante.

Recognizability. The more complex and busy things are around the specified target, the more difficult it may be to recognize. If the mission is slotted to go down during the hours of darkness, how well can the night vision systems see the intended target? Teams may have to determine in rehearsal the capability of their night vision systems to see similar targets at night under as close to target-area conditions as possible. When the target is an aircraft, how easy is it to see or place a crosshair on the intended point of attack, from differing angles, across hot tarmac with heat waves, or in fog or ground haze? Snipers may have more of a problem with this in complex sites because they are not going on the target. Assault team members may be able to carry photos or something else to help them find the critical target. A sniper team must find it visually.

A **CARVER matrix** is developed to isolate and assign the values to the above six factors. The matrix may

range from very simple and direct to a complex one that examines a target from its target system all the way down the chain to the individual target. Teams that are going to raid a target as a direct action will analyze the target all the way from the top. If the mission is to take out a power plant. They may analyze the fuel system that supplies that plant and see if it is vulnerable to contamination that will destroy the engine or turbine that makes the power. If they can destroy the power plant without going on it directly, they are in much less danger. Target “down time” is a great part of this determination process.

For a Hard-Target Interdiction team, the attack is going to be more direct. Almost always, they will attack the intended target directly and not somewhere higher up its targeting chain. The reason that a team is being used is because it is an immediate threat and planning may be only one day or a few hours. Even when the target is a single missile, you use the CARVER matrix to analyze the threat and situation in the area surrounding the target. Through this analysis you may reveal danger spots or vulnerabilities in your own methods. For sniper operations, use the CARVER matrix to not only analyze a single target, but to analyze everything in the target area. Include the target, the threat, avenues of approach to an FFP and avenues of escape. DO NOT limit the analysis to only the target itself.

This also keeps the team from super-focusing only on the specified target itself and ignoring other problems in the area. In cases where the job may be to shut down a complex with multiple targets in that complex, the team will list all targets along the side of the matrix sheet. You must develop criteria for evaluating each CARVER factor. Time may be used as a factor for Criticality. If destroying the component results in the total loss of function of the missile site, then that component is very critical. If the missiles can be replaced by the supply system before the attack may occur, that particular component is not as critical. This also ties in with Recoverability.

Once the evaluation criteria has been established, use a number rating system to rank the CARVER factors. This may be from 1 to 5 or 1 to 10. The higher the number, the more desirable that factor is to the team. For example, in the display below, a number “10” assigned to the Radar Control Van indicates that target is the most critical member on the target list. The numbers correspondingly go down in value for the less critical components on the missile site. Some types of target complexes have targets that are not located on that specific geographical location. An anti-aircraft missile site may have a look-down radar placed on a piece of high ground designed to deny enemy aircraft a certain low-level approach route. By removing this radar site, the team will remove that site’s shoot-down capability even though the missiles are intact. The remote radar sight, by being on the high ground, may be much more vulnerable than the missile site itself.

You must carefully consider your evaluation criteria and select measurable, quantified criteria to the maximum possible extent. Apply this criteria vigorously and be objective. Do not allow subjectivity to enter into the evaluation process. This is the most common mistake when operators are discussing matrix criteria. As the individual targets are weighed for their six factors, enter the number value assigned to it. It does not matter if you do all six factors for each target or do a factor (criticality for example) for all six targets before moving onto the next factor. Once all of the data is filled in, add across the totals for the six factors for each target component. Attack first the components with the highest value. As time and your mission permits, attack each target in order descending from the highest value to the lowest. The following are examples of a 1-5 rating system for an anti-aircraft missile site that is going to be analyzed in the example for this process. Items that cannot be determined will be given a 2 value.

Criticality

Single volley will make the site a non-threat to U.S. aircraft.	5
Single volley will reduce the site’s anti-aircraft capability.	3
Single volley will have an undeterminable effect on the site.	1

TARGET ANALYSIS

Accessibility

Target is of sufficient size to allow maximum standoff under SAC.	5
Target must be engaged under 1,000 meters due to size of component.	3
Target must be engaged at under 600 meters due to size of component.	1

Recoverability

Elimination of the component will definitely shut down site for 6 hours.	5
Elimination of the component may shut down site for 6 hours.	3
The effects of elimination on the target's ability to shoot down U.S. aircraft is undeterminable.	1

Vulnerability

Component is destroyed with a single shot.	5
Component is destroyed with two volleys of shots.	4
Component is destroyed only when visible detonation occurs.	3
Effect of shots on target is not determinable.	2

Effect on the population

There will be no effect on the local population.	5
Possible reprisals against local population due to guerrilla activity.	3
Reprisals against local population likely due to local guerrilla activity.	1

Recognizability

Target component is easily recognized with NVDs under less than 30 percent illumination	5
Target identification at night is dependent on active IR illumination of the target.	3
Target must be in 100 percent illumination or daylight to be identified.	1

We are going to do a sample target analysis on a surface-to-air missile site. The task is to render the site a non-threat to U.S. aircraft that are going to penetrate through its airspace. Through the team's mission analysis and mission statement, the following constraints, limitations and facts are present.

- Eliminate the site as a threat to U.S. aircraft for a period of 6 hours on a specified date/time group. Down time window is 3 hours either side of 182400LAUG98 (from 9:00 p.m. to 3:00 a.m. on the 18th of August, 1998. Earliest down time is 2100 hours (9:00 p.m.).
- Avoid loss of life at the target as much as possible.
- Missiles are small and are carried on vehicles in armored launchers, but they are controlled by a remote radar van with automatic shoot capabilities. The remote van is located approximately 3km away at the entrance to a valley that U.S. aircraft intend to use as an ingress route.
- Avoid disclosing to the enemy the nationality of this mission (clandestine mission).
- The site has the capability to shoot down aircraft on its own but must receive permission from its higher HQ to execute a shoot down. Their communications with HQ is absolutely dependent on this site shooting at A/C.

- The enemy site security consists of a heavy squad of infantry. They have an undetermined weapons package and their strength is estimated at 14 men. An NCO whose capabilities are undeterminable leads them. Their military structure does not encourage independent and dynamic action.
- The missile is a ground mounted export version of the SA-11 Gadfly low to medium altitude missile system. Missile size is 40cm in diameter by 5.6 meters long.

CARVER MATRIX ON SURFACE TO AIR MISSILE SITE							
Targets in Complex	Criticality	Accessibility	Recoverability	Vulnerability	Effect on Populace	Recognizability	Total
Individual Missiles	5	1	3	5	5	5	24
Radar Control Van	5+	5+	5	4	5	5+	29
Communications Van	4	2 N/D	1	2 N/D	5	2	17
Command & Control Van	5	2 N/D	2 N/D	2 N/D	5	2 N/D	22
Fuel Trucks	2	5	3	5	5	5	25

Analysis of target components. This analysis is done with the consideration that the target will be attacked with .50-caliber sniper rifles only. It is based on a team configuration of four men with two .50-caliber sniper weapons systems. They have state-of-the-art Generation III night vision sights on their rifles and observation systems with Generation III capabilities. The weapons are suppressed and the team is totally sterile for this mission. They are equipped with bolt-action rifles to minimize the sterilization problem. Here is the analysis. We will take a look at all six factors concerning one target component. The + marks are assigned to a specific component when other components have the same numerical value. The + mark gives an edge to that component.

Target: Individual Missiles

Criticality: Without question, the missiles themselves are critical to the function of this missile site. If the missiles were all rendered useless, the site would be out of action. A value of 5 is given to the missiles.

Accessibility: The missiles are clearly visible and are not blocked by line of sight. There are two other problems though. First, they are in armored boxes and even using Mark 211, Mod-0 ammunition won't guarantee that the penetrator will cause critical damage after the box is struck. Second, the missile is such a small diameter (45cm) that the operators will have to be within 600 meters to accurately strike the missile, even if it were exposed. A value of 1 is determined for accessibility.

Recoverability: The unit can replace the destroyed remote missile launchers within 6-10 hours of their removal. Because of this and the time criteria, a value of 3 is assigned.

Vulnerability: This is simple, the missile, when struck is rendered useless with a single shot. Value assigned is 5.

Effect on the population: There is no guerrilla activity in the target country and no reprisals are expected against the local civilian population, value 5.

Recognizability: The missile launcher sits on top of mobile towed launcher assemblies and is very recognizable under almost anything but total blackout illumination. Expected weather is that illumination is going to be 88 percent with clear skies that night. A value of 5 is assigned to this factor.

Target: Remote Radar Control Van

Criticality: The remote radar site is very critical to the operation of the missile site. The radar locates, identifies, tracks, and orders the launch of the missiles. Without the radar site, the missiles are useless and cannot independently track and shoot down aircraft. As a stand-alone single entity, the radar is the most critical component. This component is rated 5+.

Accessibility: This component also rates a 5+ because of its remoteness and location on high terrain. After the team does a map check they find that they can engage this target from neighboring high terrain from only 1,400 meters away. There is a river between them and the target, which will impede enemy security forces.

Recoverability: Radars are much more expensive and harder to replace than missiles. The intelligence estimate is that this component could not be replaced for 7-10 days after its destruction. This component is rated a 5.

Vulnerability: Radars cannot be destroyed with only a shot to the dish. A specific component of that dish must be engaged, the van it is sitting on is easier to attack. The team has information that shows the specific points of attack on the outside of the van. The vehicle is only light-skinned. It is estimated that a couple of volleys of shots would be needed to take the target out of action.

Effect on the population: The same considerations apply as in the missile component analysis and are rated a 5.

Recognizability: The radar van is easily recognized for three major reasons. First, the type of radar has been identified and photos of it are available to the team. Second, its remote location and the fact it's the only vehicle in the area with a radar on it eliminates the need to identify a specific target from a number of others. Third, the target is standing on high ground and is silhouetted with 88 percent illumination in the target area.

Target: Communications Van

Criticality: It was stated in the fact section that the site must have authority from higher HQ to shoot down targets. The communications van is therefore very critical to the site's ability to shoot down aircraft. The reason that it is not rated a 5 is that an independent site officer can still order launch if he feels the threat is high enough to warrant not obtaining higher HQ's permission. This human factor cannot be controlled. It is assigned a value of 4.

Accessibility: This factor is touchy to apply without carefully applying the criteria presented earlier. The van is large and easy to find, but that doesn't mean it's easily accessed. The intelligence on the target is not good enough to identify the specific point of engagement on the communications van that the shooters must engage. Therefore, they cannot determine their maximum standoff range based on the size of the target. This component is assessed a 2 N/D, meaning the value cannot be accurately assessed without better target data.

Recoverability: Communications is easier to establish than the radar van. The type of communications used is not determinable, though planners can get a good idea based on the range to the nearest command and control site. The site may have a backup radio system that has not yet been identified. Based on the visual appearance of the van, the replacement of this van may take longer than six hours, but in reality is undeterminable. It is assessed a value of 1.

Vulnerability: The commo van itself is vulnerable to attack by the rifles. The problem is that the components inside may be armored or they may be difficult to hit and take the commo van out of action. The vulnerability of the van is therefore assessed a value of 2 N/D.

Effect on the population: Effect is rated 5 for the stated previous target components.

Recognizability: The team has no imagery on what this commo van looks like. It may be any type of vehicle and the only identifying feature maybe the additional antennas. At night with 88 percent illumination, these antennas may not resolve in the night vision systems the team is using. Through the NVDs, the commo van may appear as any other type of service van on the site. The value of this factor is rated 2.

Target: Command and Control Van

Criticality: The command and control van is necessary to the operation of the site because it is likely the shoot down orders will come from there. Depending on the data link between the missiles, the radar, and the C3 van, removal of this component from the target complex may be a good way to shut down the site. However, killing the commander of the site or severing a data link (which would occur by accident only, without better intelligence) is no guarantee that the site cannot function. This component is valued at 5.

Accessibility: The team has no specific data on the location of the command and control van, nor its appearance. Through careful observation they will be able to determine which van is the C3 van. Because of that, the specified target within the van cannot be determined and standoff range cannot be established. The C3 van is rated a 2 N/D.

Recoverability: The actual configuration of the C3 van is not determinable. In reality, there may be no actual C3 van—they may use a combination of the commo van and key personnel that roam around. Due to these reasons, actual replacement of the van may either be super-critical or it may mean nothing at all. Recoverability is rated at 2 N/D because it is not determinable the effect of replacing the C3 van, if there is such a thing at all.

Vulnerability: This target's vulnerability is difficult to assess without more knowledge of its configuration, or if it exists at all. The C3 van is therefore rated a 2 N/D.

Effect on the population: Effect is rated 5 for the stated previous target components.

Recognizability: The C3 van may be either easily recognized or it may not exist at all. It is therefore rated a 2 N/D.

Target: Fuel Trucks

Criticality: The fuel trucks themselves are not necessarily critical to the running of the missile site. They do provide the fuel to run the generators that the launchers are a part of. The fuel trucks provide an alternate means of destroying the missile launchers because of their close proximity to the launcher assemblies. One problem with attacking the fuel cells is that the chances of loss of life at the target area are much greater than any other mode of attack. This alternate destruction method may be considered, but as a stand-alone subject, the fuel trucks are rated a 2.

Accessibility: The fuel trucks are easily accessible. The generators for the missile launchers run on gasoline while the vehicles at the site run on diesel fuel. Mark 211, Mod-0 ammunition can ignite fuel. It does a much better job on gasoline with spectacular results and is not nearly good against diesel fuel containers. The target is easily large enough to engage from maximum standoff and maybe even a subsonic range attack. The fuel trucks are rated a 5 for accessibility.

Recoverability: Fuel trucks are easily recoverable. That is, once the fire stops or is put out. The recoverability aspect does not really stand alone because of collateral damage caused by the fire in the target area. The burning fuel may set off other munitions at which point installing new fuel trucks is moot. Because of this affect, this factor is rated a 3.

Vulnerability: The fuel trucks are extremely vulnerable to attack by .50-caliber rifle fire. The gasoline tanks are more at risk than the diesel tanks, but a single shot should ignite the fuel cells. This factor is rated as 5.

Effect on the population: Effect is rated 5 for the stated previous target components.

Recognizability: The fuel cells are the most easily recognized target component on the site, with the possible exception of the missiles themselves. The fuel tanks are large enough to be seen at extreme range with Generation III night vision optics even under all the dead zero visibility.

With the totals all added up on the chart, you can see that the target component receiving the highest value is the radar control van. At this point, stand back and take a good common-sense look at the result of your analysis. The senior man with the most experience at this point should take a look at the matrix and he should agree with it across the board if it was done right. If that man is scratching his head, maybe something

was done a bit subjectively. As you can see in the analysis, the target components fell out in a reasonably sensible priority of attack:

- | | |
|---------------|--|
| First choice: | The remote radar targeting acquisition and tracking radar. |
| Second: | The fuel trucks at the missile site. |
| Third: | The individual missiles in their launchers. |
| Fourth: | The command and control van or key officer in charge. |
| Fifth: | The communications van. |

We have completed a CARVER matrix on a surface-to-air missile site and have determined that the remote radar site is the priority of attack. This makes good sense as the van is remotely located and has minimal security. The Hard-Target Interdiction team is away from the more heavily guarded missile site itself. If the team leader decided and the chain of command approved before the team departed, the fuel trucks could be attacked as a good measure, provided some criteria is set up for that engagement. One engagement criteria may be no enemy personnel within 50 feet of the fuel cell when the shot is taken.

PRINCIPLES OF TARGET ATTACK ON MATERIEL TARGETS

The normal principles of attack were developed with the idea that an assaulting force is likely to go on a target to do its damage. With a Hard-Target Interdiction team, the specific intent is to NOT go on that target. As the following principles of attack are presented, they will be discussed in the light of the mission that we just did the CARVER matrix on.

Attack Special Target Components

For obvious reasons, attack the more specialized components that are harder to replace. This must be weighed against the level of destruction requirements. In the mission above, we attacked the radar van for a number of reasons, the major ones being its accessibility and the fact it is the most specialized piece of equipment on the site. Ancillary reasons were its remote location, its ease of recognition and the vulnerability of the target to attack.

Do Permanent Damage to the Selected Target

Do this when appropriate. In this scenario, the directive was for a 6-hour window. There was no specification that you could not do more permanent damage. However, the site had to go down for six hours. With this in mind, if the radar was attacked and disabled and the fuel trucks were engaged and destroyed as a pickup target, it is likely that the site will be taken out for good, requiring a total rebuild. The level of damage required is directly tied to this principle.

Do Damage to Selected Components that Prevents Cannibalization

If the team had elected to attack the missile components only, it is possible that some of the missiles may have been moved to other launchers and the system pieced together enough to attack targets on their way back out of the target area. In this scenario however, the aircraft are returning a different way (which is usually the case). Therefore if the target is down for 6 hours anyway, cannibalization is not a factor. By attacking the radar van, if their attack is successful, this stand alone component has no cannibalization possibility.

Attack Cast Metals where Possible

Cast metals are more brittle and are more easily cracked. This is a factor if the launcher boxes were to be attacked as many launcher boxes are cast metals. This principle is not a factor in this target analysis.

Attack the Driven Machine

This means that when you are trying to take out certain types of targets avoid attacking the vehicle that is pulling the piece of equipment/launcher. The driving machines are usually standard prime movers or the driven machine may be able to be moved by anything with enough power to do so. This principle has its roots more in point target assault operations where a team will enter a facility to take out a target. An example of this is taking out a specialized rock crusher in a refinery as opposed to the engine that is driving the crusher. Any engine may be adapted within a day or two to get the crusher up and running again. However, take out the crusher or a critical component of that crusher, the down time will be much longer.

When Possible, Cause the Target to Self-Destruct

A good example of this is the attack on a missile with a solid fuel booster. Through their target analysis the team finds that the missile target is a solid fuel system. They select M-33 Ball ammunition to shoot with because this round will not cause a sympathetic detonation of the entire missile. The team uses a suppressed rifle to shoot a Ball round through the solid fuel cell of the rocket. They time this with generator noise and the activity that is taking place around the rocket. The enemy soldiers on site do not detect the shot for a combination of reasons. This shot may be detected by later inspection or it may not. U.S. soldiers are always inspecting their stuff, but many third world countries are not so diligent. At a minimum, as weather conditions and time contaminate the fuel, the fuel may fail to ignite when the launch goes down. At best, when that exploding fuel reaches the breach point in the cell, the entire missile will go up in a spectacular blast. When a team successfully engages a target that doesn't immediately and visually explode, they increase their chances of getting away successfully and without detection. The psychological factor involved in this is fantastic for the Hard-Target Interdiction team.

MISSION/TARGET ANALYSIS OF THE SHOOTING PROBLEM

The HTI team has the layout of the site plotted and has developed the layout depicted below. This information came after the team did their CARVER matrix on this target. As you can see in the image, the missile launchers are NOT located together. The fuel tank's destruction will NOT result in the destruction of the missile launchers. What this does is further reinforce the team's decision to attack the remote radar site. The physical location and spread between the launchers almost eliminates the possibility of the team shooting the missiles. Now it's time for the team to analyze the shooting situation.

Based on the tactical and terrain situation alone, the team has selected four possible shooting positions: A through D. The team will apply their weather intelligence to these possible shooting solutions to determine if they are within the necessary range to engage the designated target with the precision necessary to reduce the target. Look at the image on the next page and check out the ranges to the targets from the different shooting positions. The team can only locate themselves in one position as per commander's constraints. The commander has determined that the team leader may not split his team on the ground. This may seem a little out of line, but it does happen. Teams on the ground are frequently hamstrung by these instructions. At this time, the team must gather its weather intelligence and begin to assess the validity of their selected positions. The predicted MET and ENV conditions and ammunition data for this area at the mission execution times are as follows:

Slant Angle to Target = Less than 1 degree to the target from any one of the four possible positions.

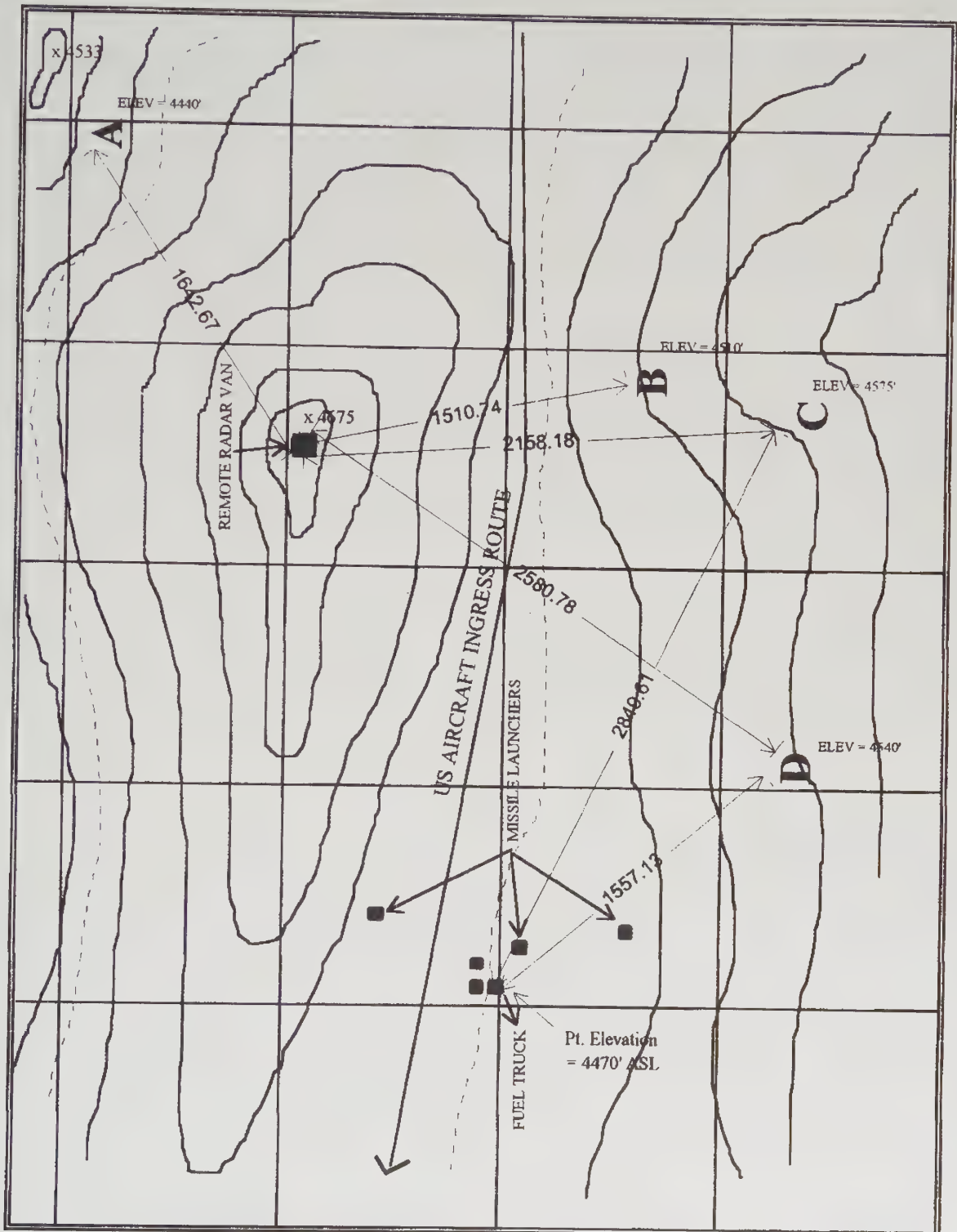
Predicted barometric pressure = 25.22 In. Hg

Predicted air temperature = 90 degrees F.

Planned ammunition temperature will be based on ambient air temperature = 90 degrees F.

Ammunition to use: Mark 211, Mod-0 Multi-Purpose and M-903 Saboted Light Armor Piercing.

TARGET ANALYSIS



Weapons system: Windrunner compact with two barrels. One barrel is for standard ammunition and one specially twisted to use with M-903 Saboted Light Armor Piercing ammunition.

The team now will calculate their shooting data based on the above conditions. They will use this data to assess the validity of these positions based on the shooting environment. You can see the progression of the analysis. First, the team selected possible positions based on terrain and the enemy situation. They nominated four possible shooting positions. These were selected regardless of range to the target, ammunition, and MET and ENV conditions. The team used a GPS to determine the range to the target by entering the grid coordinates into the GPS for the shooting positions and for the target itself. The GPS will give you the horizontal range to the target. The elevations for these targets were provided with the imagery intelligence provided to the team. The only problem with this is that the site selected by the team in planning may not work at all once on the ground. We will go through each of the four positions and breakdown the shooting analysis.

Position A to Radar Van Target

This site was selected as the best tactical position to use because the location is isolated from the missile site itself. The team can engage the radar van from here without directly alerting the security at the missile site. This gives them more distance between the team and the bad guys and a better escape route. The range to the target is 1,642.67 meters. The team has a choice of Mark 211, Mod-0 or M-903 SLAP ammo. The Greentip causes more damage because of its high explosive/incendiary projectile. The SLAP round has a much flatter trajectory and range determination will not have to be as accurate with that round as the elevation setting is 184 percent less than the Mark 211 setting. The elevation setting for Mark 211, Mod-0 is +74.00 MOA. The range at which the bullet is going to go subsonic is 1,550 meters. Note that this is about 92 meters short of the target. Mark 211, Mod-0 ammunition sometimes does not detonate against soft skinned targets when the bullet is in subsonic flight. This creates a problem if the team is going to engage with Mark 211, Mod-0 ammunition. The team now considers the use of M-903 SLAP ammo. The elevation setting for this shot is 24.25 MOA. This round is easily supersonic to the target and is traveling about 2,350 fps on impact. At this point, they team will need to further analyze the destructive power of the SLAP round on this type of target. In special operations planning environment, a request for information would go to an agency with more information on these vans. This data will be included in the final analysis.

Position B to Radar Van Target

This position was selected as the second best position. It is located closer to the radar site at a range of 1,510.74 meters. The concern was the team's relatively close proximity to the missile site. This position is located a little more than 2,800 meters from the missile site. Security patrols may patrol out this far, but their strength is small and they would only be able to patrol that far every few days, if they are doing it in a pattern around the target area. This site is a little less secure for the team, but not much less than site A. The team's other concern about B was that the team's infiltration landing zone is northwest of position A. The team would have to move around the radar van site, skirting it by a couple of kilometers to avoid detection. This would add about 3 to 4 km to the team's movement distance. The elevation setting for Mark 211, Mod-0 is 63.75 MOA. The supersonic burnout range is just shy of 1,350 meters. The team and analysts are confident that the round would strike supersonic and detonate correctly against the radar van. The elevation setting for the SLAP round is 21.75 MOA. The SLAP round is traveling about 2,500 fps on impact. From a shooting point of view, this position offers the best chance of success so far.

Position C to Radar Van Target

This position was chosen as a fallback position to B in the event that line-of-sight is bad due to the lower elevation of B. The position is located at nearly the same altitude as the target. This cuts down on the little "glitches" that can occur when the gun is above or below the elevation. As corrections are made for MET and

ENV conditions, elevation settings for positions that are above or below a target will have a little error in them. This is because of the fluctuation in the barometric pressure of the differing altitudes. This position is located 2,158.18 meters from the radar van target. Clearly, this eliminates Mark 211, Mod-0 ammunition from the engagement, leaving the M-903 SLAP round as the round to use. The elevation for "C" for SLAP ammo is 37.50 MOA after corrections for MET and ENV conditions. If the team is forced to use this position, the SLAP round will have to be used. Analysis is still being done on the effect of that round on the radar van target. The round will be traveling at about 1,890 fps on impact. Previous analysis indicated that the accuracy level of the SLAP round is good enough to strike the van target at this range. More shots on target will have to be fired to achieve an expected level of damage.

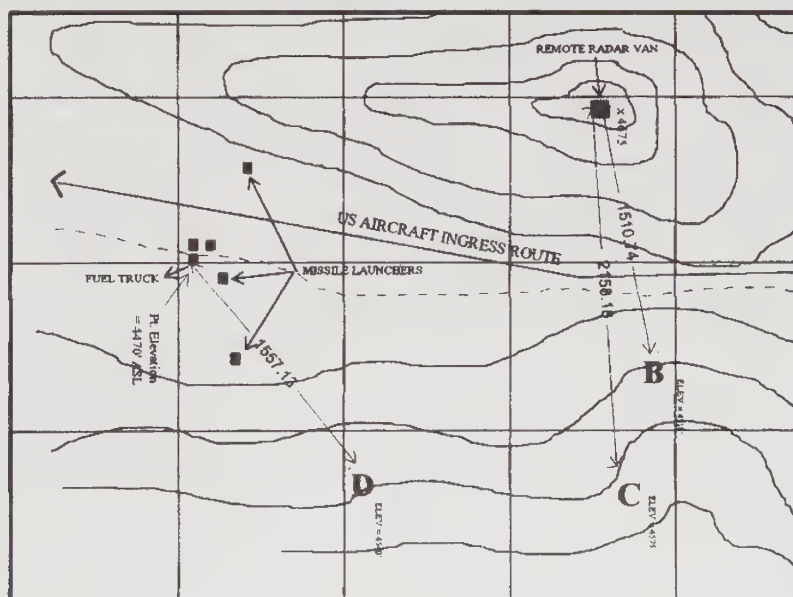
Position D to Fuel Truck and Command and Control Target

This position was selected because it is the best location to attack any targets at the missile site itself. For any reason that the team cannot attack the radar van, the team will use this position to attack target components at the launch site itself. The team will engage the fuel trucks, commo van, and any missile components exposed to reduce the target's ability to shoot down U.S. aircraft. The range to the center of the target site is 1,557.13 meters. The elevation setting for Mark 211, Mod-0 is 69.25 MOA. This location as plotted puts the center of the target components just out of the supersonic range of the bullet after corrections. The team has the option on the ground of moving about 100 meters closer. This will give them the range they need to use the Mark 211, Mod-0 round. The fuel truck is a larger target, however, and if they had to engage this target from a range of 1,557 meters, they would strike it, but the explosive cartridge may not detonate because of its impact velocity. The team could attack with SLAP ammo to dump fuel on the ground, then shoot harder steel targets to cause the round to detonate and then ignite the fuel (gasoline only, not diesel).

In all of the above situations, the team may elect to move closer to ensure the Mark 211, Mod-0 bullet arrives at the target at a velocity greater than 1,125 fps. The mission planning on paper before deployment may all go to hell on the ground. The biggest factor in the positions being used is the line of sight to the target. The team will have to move a little left and right, in or out, to get the line of sight to the target. They will then determine the real-world range to the target. They will obtain the real-world MET and ENV conditions and apply corrections to the elevation settings.

Final Analysis

This final analysis is the part of the mission planning that becomes the "Actions on the Objective" for the team's 5-paragraph operations order. The team will use a planning cell within its own team to do the target analysis and actions on the objective part of the overall planning. Once this planning cell completes its analysis and course of action, they will present it to the rest of the team. The team always has the option to "frag" the plan on the ground. ENV and MET conditions may change enough to allow the team to shoot from position A. The pressure may drop some more,



the air temperature may go up, also raising the ammo temperature. A combination of these gains may keep the Mark 211, Mod-0 bullet supersonic all the way to the target. That call will be made on the ground.

The information request comes back that it cannot be determined the level of damage caused by a SLAP round. If the round could cause the required damage on the radar van, site A would have been the best position to use. With the above information, the team decides that they will execute the target in the following manner:

The team's priority final firing position is going to be Point B. The engagement range of 1,510 meters ensures that the Mark 211, Mod-0 round will do the desired level of damage to the radar van. If necessary, the team can still engage with SLAP ammunition to enhance the destruction of the radar. From this position, there will be no attack on any other targets in the target complex (fuel trucks, commo van and/or missiles). If the team has to fall back to Point C, the attack will have to be done with SLAP ammo only. There are two reasons that may force the team to use C. Enemy patrols may be patrolling the area to a range that swallows up both points B and D. In the event the radar van is not a viable target (heavily armored, sandbagged, dug in, etc.) the team will shift its priority to targets at the missile launch complex. Point D will become the team's priority final firing position. The range is a little farther at 1,557 meters, but one of the targets is the larger fuel tanker. This is likely to cause collateral damage to the other components in the target area. From point D, the team will use a combination of Mark 211, Mod-0 and SLAP ammunition to damage the targets in the area. The risk to the team increases as more rounds have to be fired and the team has to move away from point B.

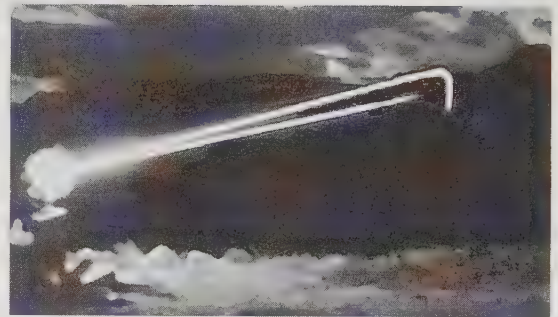
The target analysis phase of the mission planning deserves special attention. Within a team, a separate planning cell is set up to take care of this phase of the planning. That cell will do the detailed target analysis and developed courses of action for the execution of the mission. The important point to remember is redundant planning with contingencies for everything and backups for those. Remember that phase of planning where the team makes the assumption that their mission will end up in a running game called Escape and Recovery. In closing, remember a plan is only a plan. Always try to plan the execution and then execute the plan. Do not change the plan on the ground unless there is something to be gained by that change—significant gain. Changing for the sake of change only upsets the dynamics and momentum of the operation.

CHAPTER 12

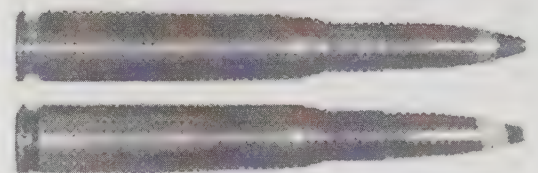
Ammunition

Ammunition for the heavy-class of rifles is in many people's opinion the most exciting and dynamic subject of small arms development. No other class of weapons system that is hand-held or shoulder-fired has seen the kind of thought, insight, and drive that has gone into the development of the .50-caliber cartridge. The civilians of the Fifty Caliber Shooters Association must be given a huge amount of credit for the development of the cartridge and its accuracy properties. I would like to thank everyone in the FCSA that helped me with this chapter—they sent me every back issue that they had and without their help, this information wouldn't exist in this text. The main push of the FCSA has been to wring out as much accuracy as possible from the cartridge for competition. The technology that has gone into this pursuit is intense and for the vast majority, paid out of the pocket of the guy trying the idea.

The intent of this chapter is to introduce the reader to the diverse world of ammunition for the heavy-class of rifles. While the cartridges in the light and medium class are pretty much limited to selecting different big company powders, bullets, cases and primers, that is not the case with the .50s. There are a number of very small shops that turn out fantastic cartridges for the .50-caliber rifles. The military approach to the cartridge design is considerably different than that of the of civilian shooter. The military develops the cartridge with



Tracer shots of M-903 SLAP against the M-17. Note the trajectory path.



This black and white photo makes it difficult to tell, however, you can see that the earlier NM140 and the newer Mark 211, Mod-0 round are visually the same except for the tip markings. The earlier cartridge had a green tip with a silver band. The current cartridge is marked with a green tip and a white band.

payload and destructive power in mind, then almost as an afterthought, they try to wring out some accuracy. Some armies procured 20mm rifles with cartridges that have horrible trajectories. The projectiles are so slow and heavy that the operators must determine the range to 1 percent or greater in some cases. In these cases, destructive power was the driving factor. In the United States and some European countries, development took a dual approach. Destructive power combined with a desirable level of accuracy was the aim of the NM-140 (Raufoss) or the now type-classified Mark 211, Mod-0 cartridge. This chapter is broken into five different sections. Some of the material clearly crosses over into some of the other areas, but that cannot be avoided.

Part I: The .50-Caliber BMG (U.S.) Cartridges. Part I is on the military cartridges that have been developed, tested, but not necessarily adopted for use. This is a historical look at the development of .50-caliber cartridges as well as the most current developments that are not classified. The section focuses on all aspects of the cartridge including bullets, cases, design and use.

Part II: Heavy-Class Cartridges Other Than .50-Caliber BMG. The heavy class starts with .50-caliber and goes up from there. Part II deals with the other cartridges that have been in use or are in use in this class of rifle. This is a historical perspective as well as a current use examination. Some of these systems have seen use in the U.S.—such as the 14.5 x 114mm Soviet KPV cartridge—and some are in use in other countries. The 20 x 108mm is in use in South Africa, for example.

Part III: The Bullets. Part III is concerned with the special bullets that have been developed by both the military and civilian communities whose main goal was high precision. There is a lot of scientific approach to the engineering and manufacturing of these special bullets. The bullets in Part III are of custom manufacture and have little destructive power other than the fact that they carry so much kinetic energy. There is no explosive or incendiary property to them. For extreme range anti-personnel sniping, however, they are the cutting edge.

Part IV: Wildcats. Wildcats are cartridges that are made by stepping down the neck size of a particular case to accept a smaller bullet. This is done to drive that smaller bullet at a higher velocity. Members of the 1,000-yard Bench Rest Club are among the early pioneers in using this method for obtaining high energy and remaining velocity for 1,000-yard competition. There is some interesting stuff here.

Part V: Reloading. The section on reloading was added after much thought. It was decided that the material is all from open sources already, so it was added. The reader is advised that the load data only applies to the weapon system that is mentioned in the article. That doesn't mean that it won't work in other rifles. When duplicating a printed load, always start with a smaller amount of powder and work up to the load that you desire. Follow the rules that are in the reloading books.

The FCSA contributed a tremendous amount of the material that makes up Chapter 12. Much of the text is taken from issues of *Very High Power Magazine*, the FCSA's official publication. Many articles are presented in their entirety. When portions are reprinted, a footnote will indicate the author and the issue number of the original article. This material is written with the full support and permission of the Fifty Caliber Shooters Association.

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PART I: THE .50 CALIBER BMG (U.S.) CARTRIDGE

A Brief History of the Cartridge

Tradition has it that the cartridge that was to become the .50 BMG we know today, was initiated at the personal request of General John “Blackjack” Pershing. This request for a heavy machine gun cartridge came in light of American experiences with the large-caliber weapons employed by the European nations during World War I. The request, in April 1918, for a weapon with an effective range of 6,000 meters and a muzzle velocity of 2,600 fps was contracted to the Winchester Repeating Arms Company. The proposed cartridge was to have both machine gun and anti-tank capabilities.

Later that same month, Winchester began the fabrication of test cartridges to obtain ballistic data.

Initially they used 16-gauge, brass shotshells, necked down to accept commercial 500-grain lead 45-70 projectiles. Propellant charges used varied from 120-150 grains, developing 2,485 to 2,944 fps muzzle velocity, and generated a (probably wildly overguessed) breech pressure of 90,000 psi.

In late 1918, work on the cartridge was transferred from Winchester to Frankford Arsenal, where it remained (almost exclusively) until well into WW2. Design work on the weapon itself was performed by John Browning and Colt.

During the ensuing years of development, the cartridge case design went through a series of metamorphoses. Case lengths from 4.08 inches to 3.80 inches were tried. Rimmed, semi-rimmed and rimless case designs were considered. Both the 13mm German anti-tank round and a scaled-up 30-06 cartridge design were copied, with the latter finally winning approval. Projectile weights from 800 to 508 grains were tested. Cartridge overall lengths from 5.51 to 5.00 inches were explored.

Eventually, advances in tank armor outpaced that of anti-tank rifles, so the .50 BMG became, exclusively, a heavy machine gun caliber cartridge. The first machine gun was standardized as the M1921 and in 1924, the Caliber .50 Browning Machine Gun Cartridge was adopted in the form pretty much as we know it still today.

The onset of WW2 initiated a surge in development of the caliber and many design concepts were investigated just prior to, during, and well after the war. Loadings tried, at one time or another over the decades, include Ball, Blank, Grenade Blank, Dummy, Proof, Tracer (numerous variations), Incendiary, Explosive, Shot, Frangible, Match, Hollow-Point, Tear Gas, Spotter, Armor Plate Test, Armor Piercing, Limited-Range Training, Short-Range Training, Limited-Range Training-Tracer, Short-Range Training-Tracer, Armor Piercing-Incendiary, Armor Piercing-Tracer, Armor Piercing-Tear Gas, Armor Piercing-Explosive, Armor Piercing-Incendiary-Tracer, Explosive-Incendiary, Explosive-Tear Gas, Incendiary-Tracer, Hi

Explosive-Incendiary-Armor Piercing (Multi-Purpose), Hi Explosive-Incendiary-Armor Piercing-Tracer (Multi-Purpose-Tracer), Practice (Plastic), Practice-Tracer (Plastic), Flechette, Armor Piercing-Discarding Sabot, Armor Piercing-Discarding Sabot-Tracer, Caseless, Telescoped, Folded, Lockless, Gyrojet, Taper-Bore, Triplex, and Bio-Chem Warfare.

Since .50 BMG cartridge inception, projectile materials tested and either seriously considered or adopted have included plastic, steel, copper, aluminum, brass, bronze, depleted uranium and various alloys too numerous to mention. The same could be said for cartridge case materials. These have included: steel, brass,



Bullets of current issue cartridges (left to right) M33 Ball, M17 Tracer, M17 (PI) Tracer and M20 API-T.

aluminum, plastic and various alloys too numerous to mention. Through the decades, there have been metal cases with metal bullets, plastic cases with plastic bullets, plastic cases with metal bullets, metal cases with plastic bullets, and even metal cases with plastic AND metal bullets.

Countries known to have manufactured this cartridge include Argentina, Australia, Austria, Belgium, Brazil, Canada, mainland China, Dominican Republic, Egypt, Finland, France, Germany, Greece, India, Iran, Iraq, Israel, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Syria, Turkey, the United Kingdom, the United States of America and Yugoslavia.¹

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One of the major problems that we encountered at the 1st Special Forces Group was decent .50-caliber

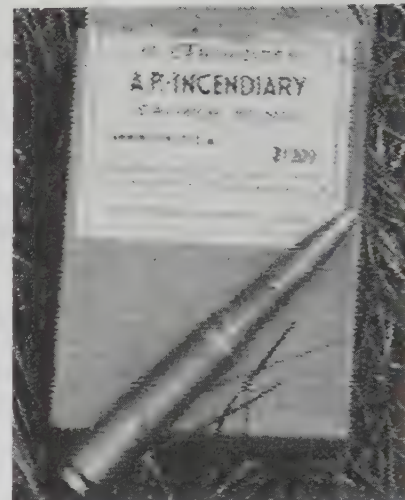
ammunition. We had the .50-caliber sniper rifles and we had the mission to use them. The problem was the only ammunition we were authorized on the books was M33 Ball linked 4:1 with M17 Tracer. That's it—only that particular combination. Something else that is interesting is, notice I said linked. Here's another little-known secret, U.S. Army installations have a policy against delinking ammunition and shooting it individually. We were prohibited from shooting the only ammunition we were issued because of a post policy letter against that.

We worked out some authorized trades with some Naval Special Warfare people who were in the area and accumulated some Mark 211, Mod-0 ammunition. The 2nd Battalion, 75th Ranger Regiment had M-8 API issued in 10 round cartons for their Barrett M82A1 rifles. They had the Raufoss ammunition on their war pallets but not for training use. The M8 API that we borrowed from the Rangers was made in a Des Moines ammunition plant in 1943. This is significant because the primers of that time were corrosive. While the cleaning procedures that were used on the heavy guns ensured the barrels were cleaned properly afterwards, we were not warned of this problem. The Fort Lewis Ammunition Supply Point (ASP) never mentioned this little tidbit of information. It was not until this author was well retired that he was informed by John Ferry, an ex-Army Ordnance Warrant Officer.²

I wonder how many units that were receiving this ammunition didn't know that their primers were corrosive and didn't have access to special cleaning equipment. When we ran the Hard-Target Interdiction course in 1996 we were able to shoot M33 Ball, M17 Tracer, M8 API, and Mark 211, Mod-0 ammunition. Operators developed different load/magazine combinations to deal with different situations. They also developed fast index changes for the optics when shooting different types of ammunition. Once they had determined the range to the targets, they knew the correction to place on the scope for the different zero changes for the different cartridges.

The major cartridges that were forming up to be the standard training and operational cartridges were the M33 Ball, M8 API, and the Mark 211, Mod-0—the M33 Ball because it is the most common, the M8 because it can defeat some hard targets and is much cheaper than the Mark 211, Mod-0 (and not much less accurate in some cases), and finally, the Mark 211, Mod-0 because it was a purpose-built cartridge by Naval Special Warfare for use with their heavy rifles. In the early years of the heavy-rifle program, all of the exterior ballistics data was based on data for the heavy machine gun. The barrels on the machine guns are quite a bit longer than those on the sniper rifles, therefore, the muzzle velocities are going to be lower. The elevation data for the MGs is totally unapplicable to the sniper rifles for many reasons. The following is a test of the three mentioned cartridges as conducted by Aberdeen Proving Grounds in 1992.

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AP Incendiary.



These two M17 Tracer cartridges appear nearly identical. The cartridge on the left is the product improved M17 Tracer (boat-tail), the cartridge on the right is the older M17 Tracer (flatbase design). The PI design is on cartridges with a headstamp date of 1994 or later.

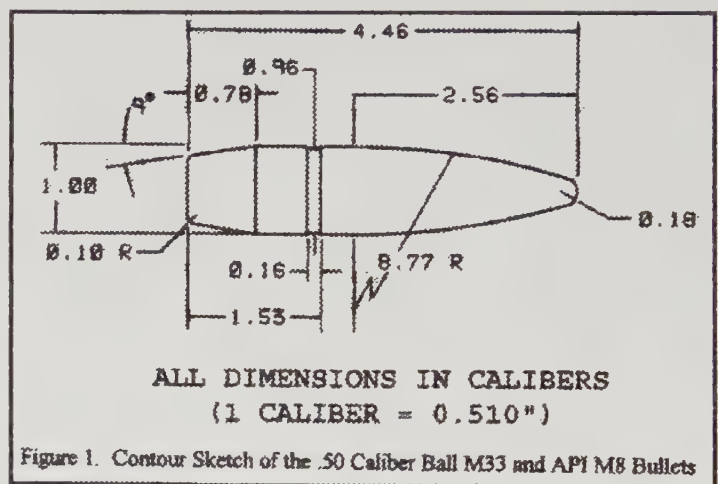
THE EXTERIOR BALLISTIC CHARACTERISTICS OF THREE CALIBER.50 MILITARY BULLETS

By Robert L. McCoy

Introduction

The fact that something has been around for a very long time does not necessarily mean that everything about it is known. A recent case in point involved the Ball M33/API M8/APIT M20 family of .50-caliber cartridges, the latter two of which were developed and fielded during the Second World War. Although exterior ballistic data were collected for these munitions at the time of their development, the instrumentation used in the 1940s was crude and inaccurate, compared with modern ballistic test equipment.

In 1987, the Fire Control Laboratory of the U.S. Army Armament Research, Development, and Engineering Center (ARDEC), at Picatinny Arsenal, New Jersey, contacted the author at the Ballistic Research Laboratory (BRL), located at Aberdeen Proving Ground, Maryland. ARDEC was involved in a fire control study, and they needed accurate exterior ballistic data for currently fielded .50-caliber ammunition. The author reviewed the existing caliber .50 data base, and advised ARDEC that no modern testing of the half-century old munitions had ever been done. ARDEC provided ammunition



and funding, and in the spring of 1988, the author conducted spark photography range tests of the M33/M8/ M20 family of ammunition in the BRL Aerodynamics Range. The spark range tests provided modern, high-precision measurements of the significant aerodynamic forces and moments that acted on the .50-caliber bullets, at supersonic, transonic and subsonic speeds.

During the spring of 1992, in support of a Marine Corps project, Doppler radar tests of the Ball M33, API M8, and the Raufoss, MK211 Mod 0, Grade A, Multi-purpose munitions were conducted at Aberdeen Proving Ground. The test weapon was a caliber .50, Barrett M82AI Semiautomatic Rifle, mounted in a machine rest, and fired at a gun elevation angle of approximately 15 degrees above the horizontal. Two radar systems were used for this test: a Weibel Doppler Radar, Model W-680, to obtain projectile velocity from the muzzle out to about 500 meters range, and a Hawk Radar Doppler Velocimeter, Model AN-MPQ-33A, to track the projectile's flight, and to measure the velocity out to approximately 3,000 meters range. The test results for the Ball M33, API M8, and the Raufoss MK211 Mod 0 are presented in this article, as examples of the high precision measurements that are routinely made today on ordnance proving grounds.

Aerodynamic Drag Coefficients from Radar and Spark Range Testing

Figure 1 is a contour sketch, showing the nominal dimensions of the caliber .50 Ball M33 and the API M8 projectiles. The MK211 Mod-0 projectile contour is very similar, except it

has an 11 degree boattail angle, instead of the 9-degree angle of the M33 and M8 designs. Average measured bullet weights were 647 grains, 648 grains, and 670 grains, respectively, for the M33, M8, and MK211, Mod-0 bullets. The reference diameter for all the bullets is .510".³

Ten test rounds of each bullet type were fired over the radar instrumentation. Muzzle velocity was recorded for each shot by the Weibel Doppler Radar. Meteorological data, including air temperature, barometric pressure, relative humidity, and air density were recorded every half-hour at the firing site. Wind speed and direction at the test site were recorded in five-minute intervals, and meteorological data aloft, including wind measurements, were obtained periodically at altitudes up to the maximum ordinate of the trajectory.

The radar data reduction utilized a computer program that determined the drag coefficient from the radar-measured velocity and time of flight. This method uses an inverse solution of the trajectory differential equations of motion, and it provides many values of the drag coefficient, C_D , with corresponding values of the Mach number, along the projectile's flight path.

Plots of the radar and spark range drag coefficient data, C_D versus Mach number, are shown in Figures 2 through 4, for the three .50-caliber ammunition types. Note the very good agreement between the radar and the spark range data, for the M33 and M8 projectiles. No spark range firings were done with the MK211 Mod 0 ammunition, because this bullet contains an explosive charge, and safety regulations prohibit firing high explosive ammunition in the BRL Aerodynamics Range.

Figure 5 is a smoothed summary plot, showing the variation of the average drag coefficient, C_D , with Mach number, for the three bullet types. All three curves were extended up to Mach 3, and downward to low subsonic speed, with the help of the spark range data. At supersonic speeds, the API M8 bullet shows about 2 percent higher C_D than the Ball M33 design; the Raufoss MK211 Mod 0 projectile has a drag coefficient that is approximately 8 percent higher than that of the Ball M33, at supersonic speeds.

Form Factors and Ballistic Coefficients for the Caliber .50 Military Bullets

U.S. military ordnance no longer uses the Siacci method for the calculation of trajectories.

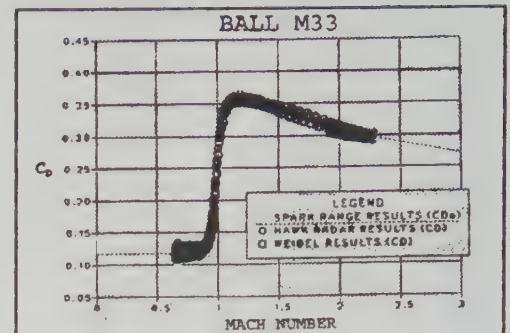


Figure 2. Radar Drag Coefficient versus Mach Number, Ball M33 Bullet

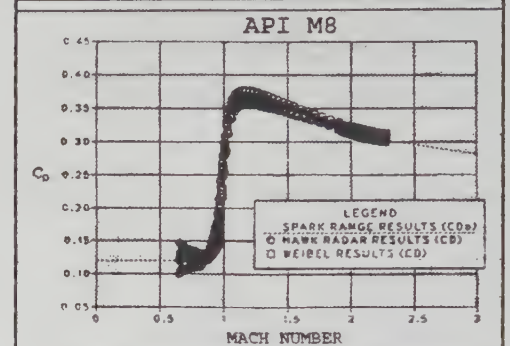


Figure 3. Radar Drag Coefficient versus Mach Number, API M8 Bullet

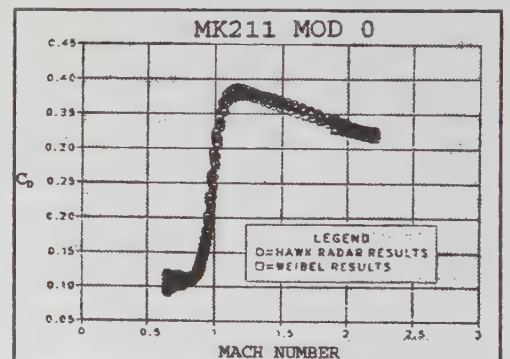


Figure 4. Radar Drag Coefficient versus Mach Number, MK211 Mod 0 Bullet

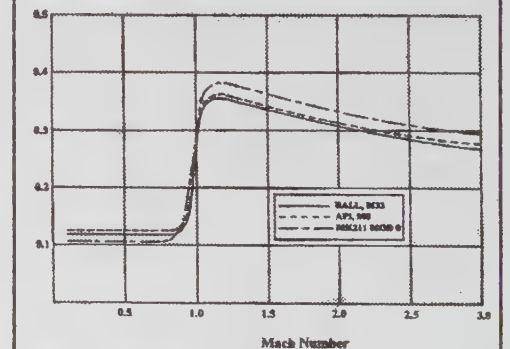


Figure 5. Drag Coefficient versus Mach Number, Caliber .50 Military Bullets

Instead, today's ordnance trajectories are calculated using the actual measured drag coefficient versus Mach number curves (as illustrated in Figure 5), and modern high speed digital computers, using the method of numerical integration. However, the U.S. small arms industry has universally retained the older methods, and the Siacci method, using the old GI drag function, has become the de-facto standard for nearly all currently available commercial exterior ballistics software.

The definition of the ballistic coefficient, C_i , relative to the GI drag function is given by the simple equation:

$$C_i = W/(id^2)$$

C_i is the ballistic coefficient relative to the GI drag function (lbs./in.²)

W is the bullet weight, in pounds (grains divided by 7000)

i is the form factor relative to the GI drag curve

d is the projectile reference diameter (.510", for the bullets of this article)

The form factor of a projectile, relative to the GI drag function, is defined as the ratio of the projectile's drag coefficient to the drag coefficient of the GI projectile, at fixed values of the flight Mach number. The value of the form factor usually varies with the flight velocity along the trajectory, as we will see presently.

Figure 6 illustrates the variation of the GI drag coefficient, versus Mach number, and includes a contour sketch of the G1 projectile shape. It is evident that the shape of the old G1 projectile is not at all similar to that of the .50-caliber bullets considered in this article, and we would therefore not expect the shape of a .50-caliber drag coefficient versus Mach number curve to be similar to the shape of the GI drag curve. This fact is confirmed in the next graph.

Figure 7 is a plot of the form factor i , versus velocity, for the three .50-caliber bullets considered in this article. The form factors were computed by dividing the .50-caliber drag coefficient by the G1 drag coefficient, at many fixed Mach numbers. The velocity corresponding to each Mach number is simply the product of the Mach number and the speed of sound in air, which is 1120.27 fps (feet per second), for sea-level, standard atmospheric conditions.

Note in Figure 7 that for velocities above 1400 fps, the variations of the form factors with the flight velocity are not large. However, at transonic and subsonic speeds, the form factors vary wildly with changes in the flight velocity. This is because the shape of the GI drag coefficient versus Mach number curve is markedly different from that of a .50-caliber drag coefficient curve, in those velocity regions.

Finally, the variation of the ballistic coefficient, G_1 , with flight velocity, is shown in Figure 8, for the three .50-caliber bullets. The ballistic coefficients are found by dividing the bullet's sectional density, (W/d^2) , by the form factor, at many different flight velocities. Again, at velocities above 1400 fps, the ballistic

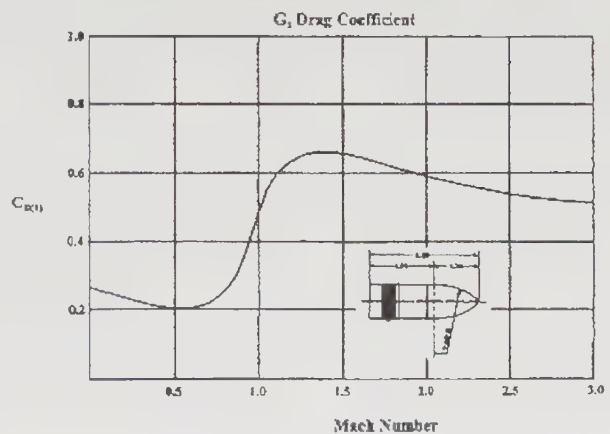


Figure 6. Drag Coefficient versus Mach Number, G₁ Projectile

coefficients of the three bullets show only minor variations with the flight velocity, and an average value may be computed that will accurately represent the exterior ballistic performance over the supersonic velocity region. At transonic and subsonic speeds, the wild fluctuations observed in the ballistic coefficient values do not permit an accurate Siacci trajectory calculation, unless the ballistic coefficient is allowed to vary with velocity.⁴

Average ballistic coefficients, for velocity intervals of 3500 fps down to 1400 fps, .50-caliber bullets discussed in this article. The results are shown in Table 1. Note the standard deviation in ballistic coefficient, listed in the last column of Table 1. The standard deviation is a statistical measure of variation, and for our .50-caliber bullets, it indicates a variability of only a few percent in C 1 over the entire supersonic speed region.

The ballistic coefficients listed in Table I may be used with any

commercial exterior ballistics software that is based on the GI drag function. Comparison of Siacci trajectories (using the ballistic coefficients of Table 1) with the results of exact numerical integration, shows that the downrange velocities predicted by the Siacci method are correct to within 10 fps at all ranges, as long as the velocity remains above 1400 fps.

As an example, the results of Siacci trajectory calculations for Caliber .50 Ball M33 ammunition are illustrated in Table 2. The observed muzzle velocities for Ball M33 ammunition were 2950 fps, when fired from the 45" barrel (Browning M2 Machine gun), and 2735 fps, when fired from the 29" barrel (Barrett M82A 1 Rifle). The ballistic coefficient used was 0.680 lbs./in.², and the line-of-sight was assumed to be 2.0" above the bore centerline, for all trajectories. The first three columns of Table 2 show the gun elevation angles required to hit targets out to 1200 yards range, for a muzzle velocity of 2950 fps. The last three columns of the table provide the same information, for the 2735 fps muzzle velocity. All trajectories were run at sea-level, standard atmospheric (Army Standard Metro) conditions. The two cases illustrated in Table 2 can be used as baseline cases, to check out commercial exterior ballistics software for use with caliber .50 projectiles.

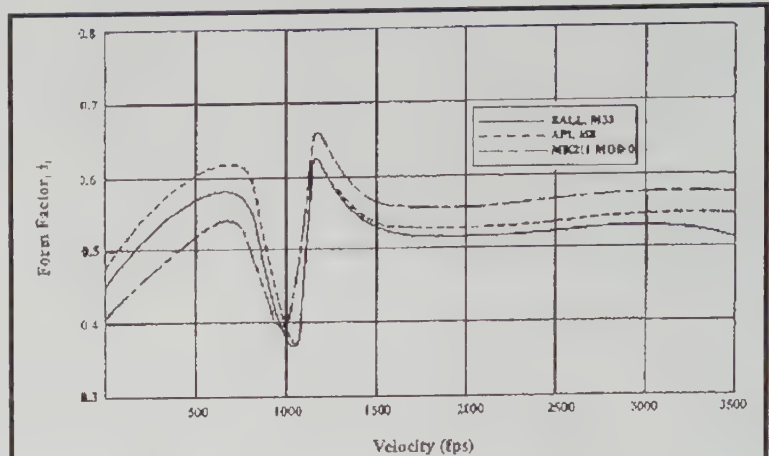


Figure 7. Form Factor (i) versus Velocity, Caliber .50 Military Bullets

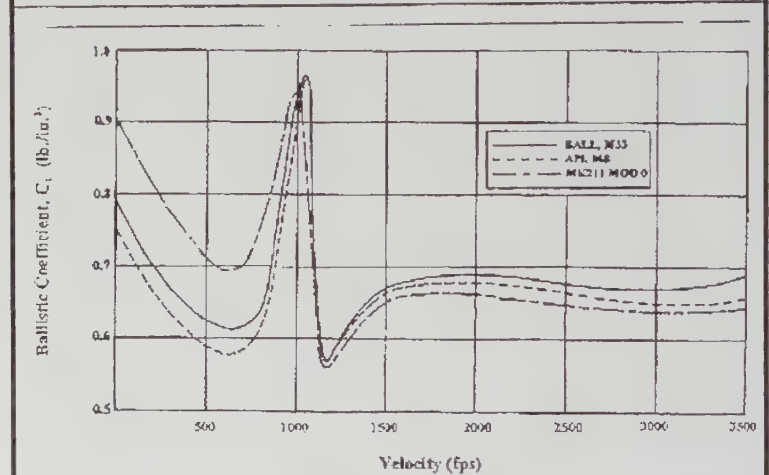


Figure 8. Ballistic Coefficient (C_1) versus Velocity, Caliber .50 Military Bullets

Muzzle Gyroscopic Stability Factors for the Caliber .50 Military Bullets

The gyroscopic stability factors of the Ball M33 and the API M8 bullets, fired from a 45" long Mann barrel with a rifling twist rate of 15" per turn, were measured in the BRL Aerodynamics Range, in the 1988 firings. Later spark range testing provided gyroscopic stability measurements for an inert-loaded version of the Raufoss MK211 projectile. Stability factors were also measured at reduced muzzle velocities, and values were obtained for the 29" barrel length of the Barrett M82AI Rifle. A summary of the spark range measured gyroscopic stability factor values for the three military .50-caliber bullets is shown in Table 3.

Inspection of the gyroscopic stability factors listed in the last column of Table 3 shows that all three bullets, from both barrel lengths, are more stable than necessary from a 15" twist of rifling. A muzzle S_g of 1.2 is generally considered adequate, if cold weather firing at sea level is not required. If the above three .50-caliber bullets are the only bullets that will be fired from a given rifle, that rifle would benefit from a rifling twist rate of 18" per turn, instead of the usual 15" twist. The observed benefit would be approximately a 20 percent improvement in accuracy, that would result from using the slower twist of rifling. However, if other brands and weights of bullets are to be fired from the same rifle, a check on the gyroscopic stability of these other bullets should be made, before changing the twist from the standard 15" value.⁵

The prior article illustrates how modern, high precision instrumentation is used to measure aerodynamic drag, and shows how the measured drag coefficients are converted into average ballistic coefficients, for use at supersonic speeds. It also shows why there are problems with the Siacci method and the GI drag function, if trajectories are required, whose velocities drop off into the transonic and subsonic speed regions. The drag measurement error with modern ordnance proving ground instrumentation is less than 1 percent error in CD.

Many shooters today have two or more chronograph, and we often see in print that a shooter has "measured" the ballistic coefficient of some bullet by setting up one set of photoelectric screens near the gun and another out at some convenient distance and firing through both chronographs. In principle, this method is correct, but there are many subtle factors that affect the results and are often overlooked, or improperly measured. After examination of a number of such "ballistic coefficient determinations," I have concluded that the average shooter typically makes a 5 percent to 10 percent error in such measurements, and I have seen errors as large as 30 percent in the reported B/C value.⁶

A good modern, aeroprediction code, such as the author's "MCDRAG" computer program, can estimate a drag coefficient versus Mach number curve, that is within 5 percent

Table 1. Ballistic Coefficients of Three Caliber .50 Bullets at Supersonic Velocities

Bullet	Velocity Interval (fps)	Ballistic Coefficient, C_1 , (lbs./in. ²)	Standard Deviation in C_1 (lbs./in. ²)
Ball, M33	3500-1400	0.68	0.008
API, M8	3500-1400	0.663	0.01
MK211, MOD 0	3500-1400	0.649	0.009

Table 2. Gun Elevation Angles and Striking Velocities for .50 Ball M33 Ammunition
(Army Standard Metro — Sea-Level, Standard Atmospheric Conditions)

.50 Ball M33 - Muzzle Velocity = 2950 fps			.50 Ball M33 - Muzzle Velocity = 2735 fps		
Range (Yards)	Gun Elev. Angle (Min.)	Striking Vel. (fps)	Range (Yards)	Gun Elev. Angle (Min.)	Striking Vel. (fps)
200	5	2676	200	5.7	2474
400	9.2	2418	400	10.7	2227
600	14.4	2174	600	16.8	1994
800	20.5	1945	800	24.1	1778
1000	27.7	1732	1000	32.7	1579
1200	36.2	1538	1200	42.8	1402

Table 2 can be used as baseline cases, to check out commercial exterior ballistics software for use with caliber .50 bullets.

Table 3. Muzzle Gyroscopic Stability Factors for Three Caliber .50 Bullets

Bullet (Inches)	Barrel Length Rate (in./Turn)	Rifling Twist (in.)	Muzzle Velocity	Muzzle S_g
Ball M33	45	15	2950	1.8
Ball M33	29	15	2735	1.7
API M8	45	15	2950	1.9
API M8	29	15	2735	1.8
MK211 Mod 0	45	15	2930	2
MK211 Mod 0	29	15	2715	1.9

of the correct answer, at supersonic speed. Thus, Mann optical comparator measurements of the bullet contour, combined with a good estimated CD versus Mach number curve from a modern aeroprediction code, will often provide a more accurate ballistic coefficient value than the usual chronograph measurement.

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Fifty-caliber BMG cartridge design has always been in a state of flux. Changes were and are constantly being made to the bullet, case and total design. Sometimes these changes were generated from the user up, and other times, they were generated at the manufacturer and simply placed into the field. The following article offers an excellent insight into some of the developments of .50-caliber ammunition. It specifically addresses Tracer ammunition and its development through the years. It is stated in the article that the tracer shots that were to be linked with Ball ammunition were supposed to have the same flight characteristics. During the course of Hard-Target Interdiction training where operators periodically loaded a tracer shot, it was observed that tracers typically struck about 1.5 minutes to the right and about 4-6 minutes high.

An interesting fact about tracers is that they strike high because of the heat of the tracer compound burning in the bullet. As the heat escapes from the back of the bullet, it tends to clean up the turbulence behind the bullet in flight. This effectively raises the ballistic co-efficient. Operators were trained to determine the difference between the tracer and non-tracer cartridges they were shooting and record that change. Observers noted the possible minute of angle changes to their shooters when tracers were going to fly downrange. For example, if a tracer were loaded every third round in a magazine, the observer would track the shots, and call out tracer to the shooter. The shooter would hold off the correct amount for the range at which they were shooting.

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NEW U.S. MILITARY VARIATIONS ON THE .50 BMG CARTRIDGE

by Keith Pagel, Staff Columnist, Very High Power Magazine

Declared obsolete by many small arms “experts,” the .50-caliber Browning Machine Gun cartridge soldiers on towards its 80th birthday. In fact, under current planning, the caliber stands a better than even-money chance at surviving past its 100th birthday.

Derivatives of the .50-caliber cartridge can be found from WW2 (.30/.50, 16mm Vega, etc.) to the present (.50 FCSA, .500 Whisper, etc.). Some concepts, such as the .50/20mm series, have repeatedly risen from the ashes like a Phoenix. A reinventing of the wheel as it were.

These metamorphoses you’ve seen to date, in the series “The Other Fifty Caliber Cartridges,” serve to illustrate that progress isn’t a straight line, but a series of zigs and zags and double-backs with much stumbling along the way.

As you can tell by this evolutionary process, the .50 BMG is still quite vigorous; especially for an

eighty year-old design. While some have declared it obsolete, and of projects to “improve” upon the caliber have come the .50 BMG cartridge itself continues to serve.

... (Thanks) in no small part to the efforts of civilian match competitors (the BMG) now has the additional roles of competition and sniper. While the cartridge’s traditional roles have shrunk somewhat in the ground-infantry and air-to-air combat fields, it has continued or even expanded in the vehicular-mounted, naval-craft, air-to-ground, and sniper roles; with the latter showing the most future promise. In fact, what started as a short-hand way of describing the cartridge (i.e. referring to it as “.50 BMG” rather than “.50-caliber Browning Machine Gun”), has now become a way of not only describing the cartridge, but of de-emphasizing its original machine gun function as well. With match, competition, police/military sniper, and military anti-materiel as well as EOD roles, the .50-caliber Browning Machine Gun cartridge is (to borrow a phrase) “not just for full-autos anymore.”

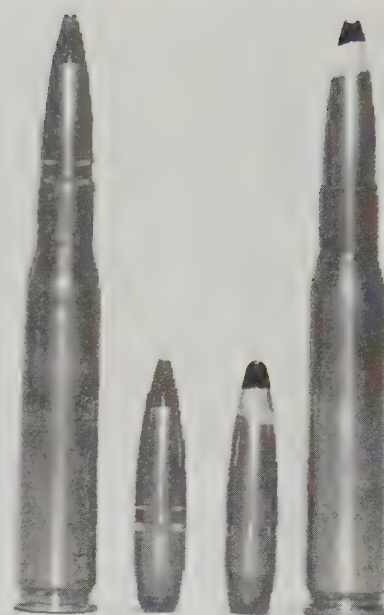


Exhibit #1: The latest variations of U.S. manufactured .50 BMG caliber ammunition. Left to right: The newly redesigned (or product improved) M17 Tracer and the new tip color designator for the existing Mk211 multi-purpose cartridge.

The Latest Releases

Starting with 1995 production (although some headstamps may appear with dates as early as 1994), those who have frequent contact with military issue fifty caliber ammunition may notice some changes. In one instance, the cartridge’s projectile has been completely redesigned but bears the same nomenclature and identification as before. In the other, the identification has changed but the cartridge, itself, remains the same. These changes, combined, affect a large portion of the .50 BMG ammunition produced from this point forward. In fact, all current, U.S. production, .50 BMG ammunition that has a tip color applied to the projectile is, in one form or another, impacted by these changes.

The two news stories below are an exclusive for VHP. This is the first time that this information has been unveiled in the open forum of a general-interest, civilian, publication. It has not yet been seen outside of military/technical publications. The first change is one your VHP staff has been monitoring for many months, beginning back when rumors first appeared. It is but one story that we have been tracking, waiting for developments to progress to the point where we can publish. Watch for future articles as these other stories develop. This first change in .50-caliber, U.S. military issue ammunition involves the tracer round.

Tracers, Tracers, Tracers

Since the initial development of the .50 BMG cartridge in the early 1920’s, a tracer version has always been around. In its lifetime, the .50 BMG Tracer has seen many iterations. In just the “basic” tracer designs, there have been 10 major versions. (The phrase “basic tracer” will be used in this article to describe those tracers specifically designed to match, ballistically, just the AP or Ball round and exclude the “dual-purpose tracers” such as I-T, APFF, MP-T, SLAP-T, etc.).

These have included the original M1923 Tracer, which had no tip color to designate its role. It relied on, instead, a chemically darkened brass case. This was changed, as you might



The "basic" tracer lineup (not including the dual-purpose tracers such as the APT, APIT, etc.) Left to right and roughly in order of developments: M1923 (no tip color, blackened case), M1924E (no tip color, blackened case), M1 (red tip, standard case coloration), Ranging Tracer (green/red tip), Delay Tracer (plain tip/red band), M1-alternate design (red tip), M1 (pink tip), M2 (white tip), M10 (orange tip), M10E1 (orange tip, green primer sealant), M17-early design (maroon tip), M21 (red tip), M17-steel case (maroon tip), M17-aluminum case (maroon tip), M17-late design (brown tip), M17-green tracer (green tip) and M17 product improved (brown tip).

have guessed, since it looks just like a ball round whose case has darkened naturally with age. A 733-grain projectile, generating 2450 fps MV, with a 2500-yard tracer burnout range, the M1923 was the first of the "issued" tracers. It stayed in service until eventually replaced by the faster/lighter M1 Tracer in 1929.(1) (Historical Note : Recent research has given rise to suspicions surrounding some of the details of the M1923 Tracer. One theory has been forwarded even doubting its existence. For the purposes of this article, the information last published on the subject in "The History of Modern U.S. Military Small Arms Ammunition- Volume I" will be used. It is the most definitive piece on the subject to date and can be reasonably considered valid until opposing details are proven.)

In addition, (and roughly in order of development) there have been the:

M1923E Tracer (Plain tip, blackened case) An attempt at improving the M1923 Tracer's performance, manufactured only in 1923, it featured a heavier (770-grain) projectile, which was 2.552 inches long and boat-tailed.(1)

M1924E Tracer (Plain tip, blackened case) Also an attempt at improving tracer performance, this 779-grain projectile had a massive 2500-yard trace range. It, likewise, was manufactured for only one year (1924).(1)

M1 Tracer (Red tip) The first design to utilize tip colors for identification, but it started life in 1929 as the T2E3, with only a blackened case for identification. At 681 grains projectile weight and 2830 fps MV, it had a 2000-yard tracer burnout range. The M1 was eventually abandoned near the end of WW2, in favor of the newer designs.(1)(2)

Ranging-Tracer (Green tip/Red band) Known as the T7E1 and developed from 1931 to 1934 at the request of the Coastal Artillery for range estimation purposes. A 682-grain projectile, with 2830 fps MV, and a 2400-yard tracer burnout range, its trace color changed from green to red at approximately 1,000 yards. Red/White and White/Red variations are also known. (1) The concept was abandoned when it was found to be an impractical sighting aid to gunners.(6)

Delay-Tracer (no tip color/Red band) Developed from 1932 to 1938 at the request of the Coastal Artillery to improve gunner vision and provide a longer trace.(1) The projectile's trace didn't become visible until well down range.

M2 (Short-Range) Tracer (White tip) Developed in 1940's at the recommendation of the British from their early WW2 experiences. A 710-grain projectile with 2740 fps MV, and a 550-yard tracer burnout range. Production ceased in 1943 in favor of the other designs being developed.(2)

M10 (Dim/Bright) Tracer (Orange tip) Developed as the T12 starting in 1943 at the recommendation of the Army Air Corps to reduce night blindness of aircraft gunners. The trace starts out dim and goes to bright at 150 yards. A 680-grain projectile, traveling at 2900 fps, and with a 1900-yard tracer range. (2)

M17 (Long-Range) Tracer (Maroon or Brown tip) Developed as the T9 in 1942, originally at the recommendation of the Anti-Aircraft Command to match 37mm and 40mm AA gun tracers. The M17 is a 649-grain projectile (2), with a 2860 fps MV (3), and a tracer burnout at 2500 yards. (2) Later adopted for a variety of roles from air-to-air, air-to-ground, and ground-to-ground, it's the only one of these "basic" tracer designs still in current production. Since 1950, a small metal foil or vinyl disk has been in the projectile base to protect the tracer element from deterioration; low shelf-life being a major tracer problem prior to this modification. In 1952, the tip color code was changed from maroon to brown.(7)

M21 (Headlight) Tracer (Red tip) Designed, starting in 1942, for its possible psychological effect on enemy pilots. They could see the projectiles coming right at them. Essentially a standard tracer, but with 100 percent igniter compound instead of the more typical igniter/tracer mix in the projectile. A 704-grain projectile(2), with a muzzle velocity of 2840 fps(3), and 550-yard tracer burnout range.(2)

Besides these major tracer variations, there remain several minor ones as well. Among these tracer "sub-species" are the:

M1 (Alternate) Tracer (Red tip) An M1 Tracer with a steeljacket clad in copper. (The original M1 has a copper or "gilding metal" jacket.) A WW2 experiment in 1942 to conserve copper, a strategic material. The T2E8 was so successful, all "basic" tracer designs since then have used this jacket. A 645-grain projectile, the M1 (Alternate) has a 2990 fps MV(2) and a 1800-yard tracer burnout range.(5)

M1 (Pink tip) Tracer Merely a standard, 644-grain, M1 (Alternate) Tracer from the St. Louis Ordnance Plant, circa 1943, but with an unusual shade of red as a tip color (quality control standards being somewhat more relaxed during the pressures of WW2 production).

Experimental Case Material Tracers Steel and aluminum were tested at various times as an alternate case material to replace brass, again, due to the strategic materials status of copper. This was pretty much rejected due to corrosion and production problems, although it has been tried repeatedly since WW2.

Experimental High Anneal Tracer An M1 Tracer projectile loaded in a standard brass case, whose neck received a special heat annealing to prevent metal seasoning (metal aging) cracks. FA 41 through 43 brass with a star in the headstamp was used.(2)

M10E1 High-Velocity Tracer (Orange tip) Utilized a standard M10 projectile, case, and primer, but with a special powder to raise the muzzle velocity to 3100 fps. Intended to shorten a projectile's time-of-flight for air-to-air engagements, the M10E1 was developed during 1945 by Frankford Arsenal and designated differently from the standard M10 by its green primer sealant. It was abandoned due to extraordinary muzzle flash, bore erosion, and erratic pressure problems.(2)



The "basic" tracer projectiles, left to right and roughly in order of development: M1923, M1924, M1, M1 (alternate), M1 (pink tip) M10, M17 (early), M17 (late), M21, M17 (PI), and a M33 Ball for comparison. Note the different projectile bases and consequently, a different flame column.

M17 (Green) Tracer (Green tip) Developed for the U.S. SOCOM for Desert Storm. Identical to the original M17 Tracer, except for a green rather than red tracer compound. Intended to cause confusion behind Iraqi lines when fired, as the COMBLOC calibers (predominately used by the Iraqis) produce a green trace while the U.S. and NATO use red. With a 643-grain projectile weight, a 2860 fps MV, and a 1600-yard tracer burnout range; all other cartridge specifications on accuracy, range, pressure, etc. for the green version are listed as "comparable" to those of the original red tracer.

Tracers—A Look Inside

The current "basic" tracer issued by the U.S. military is the M17. Now set at a 1600-yard maximum trace(3), the bullet is essentially a projectile jacket filled with tracer compound. The M17 jacket is mild steel, coated with copper and is known as a GMCS jacket (Gilding Metal Clad Steel). This construction means the projectile will attract a magnet over 100 percent of its surface. The projectile is marked with the Brown tip color code and further identified by two knurled cannelures; one for case mouth crimping, the other for identification.

All the "basic" tracer designs have one thing in common: Being tracers, special production techniques are needed for the projectiles. Unlike most other designs, which are a copper (or "gilding metal") jacket around some kind of new core, the tracers are just a projectile jacket, filled with chemicals, and contain a small metal slug in the nose only for ballistic stability. The machinery used to produce tracer projectiles, therefore, can not be readily switched over to production of Ball, API, APIT, etc.

Then it was noticed that since the APIT is just an API projectile whose core

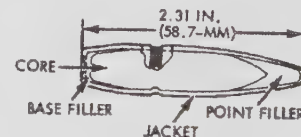
Caliber .50 Tracer M17 ("Product Improved")



FIG. 123. Cal. .50 Tracer Bullet M17 (from Dwg B7638551, Apr. 10, 1944).
Diam. .511-.0015" Weight 648-13 grs.
Length 2.40-.04"



FIG. 101. Cal. .50 Armor-piercing Incendiary Tracer Bullet, M20 (from Dwg B7638265, Mar. 10, 1944).
Diam. .511-.0015" Weight approx. 624 grs. (with alternate core, approx. 612 grs.)
Length 2.31-.00"



Cal. .50 Ball Bullet M33
Diam. .511-.0015" Weight 661-15 grs.
Length 2.31-.04"

has been drilled for tracer compound, why couldn't the standard tracer be made from a ball projectile? This Ball/Tracer concept might streamline the production process, allow for the utilization of similar machinery, reduce costs, and allow the switch-over of some of the equipment to either Ball or Tracer production as needed, relatively easily. It completely does away with the need to produce the special GNCS jackets used by previous tracer designs. In fact, once the core's been drilled and charged with tracer compound, production of this type of tracer projectile is identical to that of the ball.

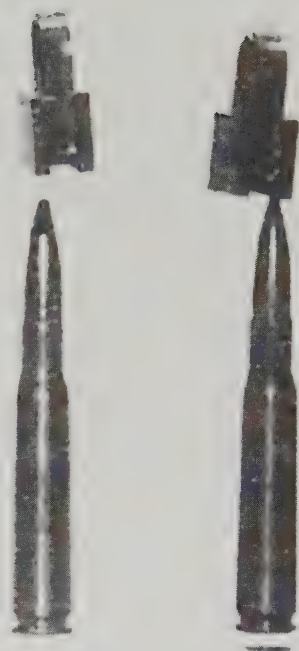
This was an idea not lost on the Brazilians, as they've been producing a similar item in their .50 BMG caliber line for some time. Combining the "Tracer" name with the NATO specification for Ball-M33, they know it as "Tracer M33." CBC's "Tracer M33" sports a Red/White projectile tip coloration, weighs 584 grains, develops 2910 fps MV, and traces from 99 to 1595 yards.(4) (Statistics based on a 36-inch barrel at 70 degrees Fahrenheit air temperature.)

M17 Tracer (Product-Improved) What IS new about this idea of a hybrid Ball/Tracer, is that the U.S. has adopted it. From this point forward, the standard, "basic," U.S., .50 BMG Tracer design will be of that construction. Like the current M17 Tracer it replaces, the new tracer provides a ballistic match to the M33 Ball, just as the M20APIT does for the M8 API. The new tracer's 618-grain projectile will travel at approximately 2910 fps MV, with a 1600-yard tracer burnout range.(8) Live rounds examined to date have contained a powder charge of approximately 235 grains of a monoperforated, extruded-type powder.

MILSPECs call for the new tracer to have identical details as the M33 Ball in terms of accuracy, muzzle velocity, and boattail construction. The M17(PI) cartridge is even approved for use with both WC860 and IMR5010 powder charges,(8) just like the M33 Ball.(3) Yet it is to retain the same 1600-yard minimum trace of its larger-capacity predecessor. (3)(8)

While the original M17 carried a tracer igniter compound of 11 grains 1508, 15 grains of red tracer mix R256, and 40 grains of either red tracer mix R321 or R284,(3) the new M17(PI) specs call for a comparatively minuscule charge of 1.2 grains of igniter compound 1280 and 10 grains of red tracer mix R256.(8) While this is a much smaller tracer compound charging than the older and heavier M17 tracer projectile, the M17(PI) tracer payload is virtually identical to that currently carried in the similarly designed M20 APIT.(3)

Despite the fact that the new M17(PI) Tracer cartridge is more like the M33 Ball (and even closer still to the M20 APIT) than the original M17 Tracer, the new design will continue to be identified as just "Tracer M 17." And although a major projectile redesign of this nature would normally result in a different nomenclature and/or model number being assigned to the new cartridge, the powers-that-be have decided to break with tradition and continue to call this new basic tracer just "M17." They are not only NOT giving the design its own M-number, but aren't even so much as tacking on a sub-classification, such as M17A1 (for which it would be in line). It has been decided that small arms ammunition will not receive these sub-designations, only medium to large calibers. Even the dark-brown M 17 tip-color will remain unchanged.



One clue to the true identity of the two U.S. manufactured M17 Tracers: The older M17 projectile has a GMCS jacket and attracts a magnet over its entire surface (right). The new product improved (PI) M17 has a gilding metal jacket around a mild steel core and as such a magnet won't attach to the very tip (left).

As you can tell by the various tracers developed over the years for U.S. service, the multitude of tip colors, functions, and M-numbers, there is sufficient precedent to establish a different model number and/or tip color for the new projectile. And as for tacking on designations to the model number of small arms ammunition, there is even precedent for that. The IVI-manufactured, 7.62 NATO caliber, "Heavy Jacket" Ball round was designated M80EI, for example. Then of course, there are the M48AI and M48A2 variations of .50 Spotter-Tracer.

Now some military end-users have expressed to this author a preference (under certain circumstances) for the original M17 over the APIT M20 as a tracer. This

is because the M20's boat-tail projectile has a smaller flame column. This makes it much less visible, especially in daylight, than the older "flatbased" M17 is. As the new M17 (one source refers to it as a "Product-Improved M17") is being constructed from an M33 Ball projectile (also boat-tailed), it will have a similar handicap. (See exhibit #5) Those expecting the familiar, wide, flame column from this batch of M17 may be disappointed.

Since the advantages to redesigning the M17 are primarily in manufacturing ease, production flexibility, cost savings, etc., the impetus to change was done from the top down. In other words, the change wasn't initiated by an end-user request, but by the purchasing and manufacturing process. Consequently, this new design's arrival may come as a bit of a surprise to those end-users. Then you can add to this surprise the fact that both the old and new M17 tracer have the same tip color code and model designation, and I'm afraid all this might eventually lead to some initial confusion among the troops normally issued .50 BMG tracer ammunition.

In fact, since the differences between the M17 and M17(PI) projectile are internal only, it's virtually impossible to tell the two bullets apart, with the naked eye, while loaded in the case. Clues to identifying them (assuming we're dealing with original, U.S. -loaded rounds, with the M17 brown tip color) would be by headstamp (94 or later date) and the magnetic signature of the projectile. Having a GMCS jacket, the original M17 will attract a magnet over its entire projectile surface, even extreme tip. The "Product-improved M17 projectile, however (having a GM jacket around a steel core), will only attract a magnet from the case mouth, up to about where the brown paint starts. The newer M17 will not attract a magnet at the projectile's very tip. Currently, the Lake City (LC headstamp) and Winchester/OLIN headstamp).



Except for the paint used to color the tips, these multi-purpose projectiles are identical. Left to right: The Mk211 MP in the original green/silver, and the Mk211 MP in the newer green/white paint. M33 Ball (far right) is shown for comparison. Although appearing more like a white, the new paint specification still refers to it as silver.

Loaded, the newer M17 (PI) Tracer cartridge (left) is virtually indistinguishable from its predecessor, the M17 (right).

Tip Color Paint Specification Change

The second change to take effect in 1995 involves .50 BMG ammunition tip color codes. Unlike the previous example, here the tip color has changed, but the cartridge remains the same. This apparent color difference is due just to a paint specification change.

Efforts to reduce the atmospheric emissions of ozone depleting substances has resulted in a change to U.S. ammunition paint specifications. When it comes to the silver used to identify some cartridges, it was found that the new (water-based, rather than lacquer-based) paint wouldn't retain the little metallic flakes that give the color its unique appearance. Without these flakes, the resulting coloration appears more like a dirty white or very light shade of gray, rather than silver. To side-step this problem, domestic ammunition sources have asked for, and received, permission to allow this shade of "white" as an alternate color. It is, however, still officially listed as "silver."

This specification change affects the .50 BMG calibers of API M8, APIT M20, and MP Mk211; but only those rounds manufactured in the U.S. . Foreign manufacture, not being regulated by the U.S. EPA, can still utilize the old, lacquer-based formulation for silver. So prepare yourself to see U.S. - headstamped and manufactured "White-tipped" M8 API, "Red/White-tipped" M20APIT, and "Green/White-tipped" Mk211 MP ammunition; alongside the more familiar Silver-tipped, Red/ Silver-tipped, and Green/Silver-tipped cartridges.

Although the tip colors on the new M8, M20, and Mk211 appear different than their predecessors, the projectiles are exactly the same design. (On a cautionary note, however, be advised that projectiles of the same type might not necessarily weigh the same. Most manufacturing specs allow for a +/- 15- grain deviation in projectile weights in the .50-caliber. This is something to keep in mind whenever engaging in ANY .50 BMG projectile loading/reloading.)

As to identifying the new tip-colored cartridges, as well as the new M17 Tracer, headstamps will be of some assistance. These changes all went into affect with 1995 calendar year production. But as manufacturers are allowed to carry over previous year's headstamped brass, up through March of the following year, some specimens may be encountered with dates as old as 1994. (Note: Specimens of the new M8 and M20 tip colors were not available to be photographed by press time.)

There are many other changes under way impacting U.S. - military issued .50 BMG ammunition, most of which are currently classified. When the security restrictions are lifted, VHP Magazine will cover these in detail. Watch for future articles on the subject.

Breaking News

In a related area, VHP readers who are interested in obtaining a fairly general technical manual on current, U.S. -military issued, small arms ammunition, may want to consider TM43- 000 1 -27, dated April 1994. Entitled "Army Ammunition Data Sheets," this recently revised, unclassified document contains some general background information on the issued cartridge calibers from .22 LR up through 30mm. It contains information on cartridge identification, use, muzzle velocity, component weights, construction, etc. While it doesn't go deeply into much ballistic or technical detail (such as ballistic coefficients), it covers a broad range of the cartridges issued by the U.S. military, including the .50 BMG. It makes a good general reference piece for your library to assist in identification.

This TM was first published in 1981 and has been kept up-to-date, over the years, with the latest changes. It was updated and reprinted in its entirety in 1994. It contains the majority of the changes that have occurred to the U.S. military ammunition line up to (but

not including) the information in this article. Examples of the latest entries contained within the 1994 edition are (in .50 BMG caliber) the M858 Practice and M860 Practice-Tracer, as well as the M903 SLAP and M962 SLAP-Tracer.

In Conclusion

All photographs are by Apex Photographic unless otherwise noted. (Copyright 1997) Specimens illustrated are from the author's collection unless otherwise noted. Numbers in parentheses above refer to sources listed at the end of this article. They indicate the information preceding was provided by the reference listed.

Also, for further information, check out the FCSA website at WWW.FCSA.ORG for the latest in FCSA news and information, including a brief overview of .50 BMG cartridge history.

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Special Bibliography to this Article:

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- (2) History of Modern U.S. Military Small Arms Ammunition, Vol. 2; F.W. Hackley, W.H. Woodin, & E.L. Scranton; 01978; The Gun Room Press.
- (3) Small Arms Ammunition Pamphlet 23-1; 8/68; Frankford Arsenal; Dept. of the Army; Philadelphia, PA; Unclassified.
- (4) Undated and Untitled CBC Pamphlet on their "12.7x99mm (.50)" caliber line of ammunition.
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- (7) Ammunition for Aircraft Guns; TM9-190 I - 1; 12/57; Departments of the Army & Air Force; Washington, DC; Unclassified.
- (8) MILSPEC MIL-C-1318; Unclassified.
- (9) Army Ammunition Data Sheets; TM 43-0001-27; 4/94; HQ Department of the Army; Washington, DC; Unclassified.

• • • • •

The standard round of ammunition that has been adopted for use in the heavy rifles is the Mark 211, Mod-0. While it has been adopted, it is in common use only in the Naval Special Warfare community. Other

units have it on their books, but only on their war pallets. This next article is an article on the historical development and current information concerning the Mark 211, Mod-0 cartridge. While it has been adopted as the standard cartridge for use, there is a good case for using non-exploding ammunition against targets that are damaged only by a penetration (missile targets are a good example). If the sniper team can get a shot off and not create secondary explosions or visual effect from the incendiary round, they have a better chance of getting away. If they have suppressors on the guns, their chances are even greater. The following article is reprinted with permission of *Very High Power Magazine*.

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SOME NOTES ON THE DEVELOPMENT OF THE HIGH EXPLOSIVE FIFTY CALIBER CARTRIDGE

by Keith Pagel

With my interest in .50 BMG ammunition, I am frequently asked such questions as: What's the best ammunition? or Which cartridge is the most powerful? As you might guess, the answers to such questions are mostly subjective.

What's best for a match competitor on the 1,000 yard firing line is different for a SEAL or Army Ranger laying his cross-hairs on the turbine section of a MIG, resting on the tarmac.⁸ What's best for the situation will depend on such things as cost, skill of the shooter, weapon used, range involved, target, desired effect, terminal ballistics, time available, and a host of other details.

A match competitor is interested in a round that has the ability to consistently print on paper to a degree equal to, or greater than, his skill and weapon can produce. A plinker can trade the inherently higher cost of a match grade round for one less accurate and consequently cheaper. While a member of the Special Operations Command of the U.S. military isn't concerned with cost, he is interested in ammo capable of greater than average accuracy and, most importantly, a unique terminal effect. (i.e., delivering the most damage to the target possible with each round fired⁹).

If you read Eric Williams' fine article on projectile design and the PRODAS software, you already know that the optimum (or best) design of any projectile depends on its intended function. While I won't presuppose to tell anyone which round is best for their circumstances, I can tell which are the most exotic in a general sense.

Of the hundreds of designs tried in the development of the .50 BMG round since its inception in 1918, only a handful have reached the production stage. And even fewer have been adopted by the U.S. military. The exotic rounds most recently adopted by the U.S. consist of the Saboted Light Armor Penetrating (M903 SLAP and M962 SLAP-T), the plastic cased/projectile M858 Practice Ball and the M860 Practice Tracer, as well as the Mark 211, Mod-0 Raufoss Hi-Explosive-Incendiary-Armor Piercing round.

While it's not much to look at upon first glance, the exotic round that is the subject of this piece is quite revolutionary in its design. Officially designated MP for Multi-Purpose, the technical description is that of HEIAP or (Hi-Explosive-Incendiary-Armor-Piercing). Its original designation (in its parent country) is NM140, for Norwegian Model



The Mark 211, Mod-0 (left) and the M-903 SLAP (right) are the two newest "attack" cartridges in use by the U.S. military, on a large scale, anyway.

number 140. But, to save time and confusion, most everybody refers to it simply by the manufacturer's name: Raufoss.¹⁰

There's nothing new about the idea of a fifty caliber HE round. Attempts at creating a successful Hi-Explosive fifty caliber cartridge (most of them very complicated in design) pre-date World War II. Even though its outside appearance is that of a typical .50-caliber ball round, the Raufoss design internal configuration is quite unique. The beauty of this design lies in its simplicity, and this simplicity is the source of its ordinary appearance.

The trick to developing an HE round, particularly in such a small envelope as the .50 BMG projectile, is to determine how impact sensitive to make the projectile. It has to be sensitive enough to detonate on the thinnest skinned target, yet sturdy enough to survive the rough handling of combat conditions in the field and the mechanism of a machine gun. One of the earliest attempts at an HE fifty carried a notation on the outside of its 10-round box, warning the user to Hand Chamber the rounds ONLY!

This potential conflict of criteria has resulted in some amazing and overly complex fusing mechanisms. The first example of fusing a round referred to as the spotlight during World War II. It has a miniature mechanical fuse. Intended to cause it to detonate on impact with an aircraft, the design was not adopted since it was overly complicated for its small usable payload.

The Pomeroy design (T1) has the appearance of a .30 caliber projectile sticking up out of a .50-caliber projectile. The green tipped center section contained a charge of Dynamite. There was also a yellow tipped version of the same design containing a different chemical mix. Its intended use was as a Hi-Explosive-Incendiary round. The Pomeroy designs were eventually rejected for use, as they failed to reliably detonate against simulated aircraft targets.

Another attempt was designed by Fabrique Nationale of Belgium in the 1960s (headstamped FN 62 12.7), it was also an attempt at creating a mechanically fused .50 projectile. It had a steel projectile body with an aluminum nose section. In trials, it didn't fare much better than any other mechanically fused .50-caliber projectile.

It wasn't until the 1970s that a major arms manufacturer in Norway went to the basics and re-thought the HE .50 concept. They made a breakthrough in the field with the NM140. Bearing a pastel green colored tip and a case headstamped IVI 84 (Canadian), this is the Pyrotechnically Initiated Explosive (PIE) design of Raufoss. Unlike the previous types, it doesn't need a complex mechanical fuse to detonate the projectile. It relies, instead, on the crushing effect of impact to ignite the incendiary compound in the tip. An old, but tried and true technique. This, in turn, detonates the explosive mixture deeper in the projectile body. A hardened steel core helps ensure penetration in the thicket targets and the presence of zirconium aids the incendiary capacity of the projectile, while providing a means of spotting the impact.¹¹

Based on the PIE concept, Winchester/OLIN began development of their own design in the 1980s. The Winchester Anti-Light Armor Piercing (WALAP) round, sporting a bright yellow, color-coded tip. Except for a slightly different internal construction, it's essentially a Product Improved Raufoss NM140 projectile. WALAP is no longer being considered for production, either due to insufficient demand, excessive cost, or the fact that OLIN is the U.S. licensee for the Raufoss product.¹²

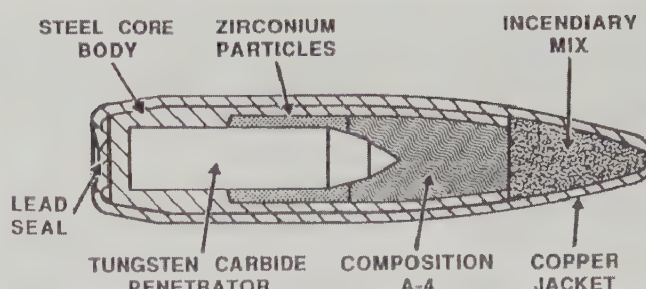
The Navy's adoption of the Raufoss NM140 is called the Mark 211, Mod-0 and was adopted for use by the SEALs. Differing from the original NM140 design only in its sensitivity to impact, this specimen of the NM140A1 is headstamped 50 FNB 91 and carries the standard USN tip color code of Green/Silver.¹³ Although there are specimens with the FN headstamp, it was loaded in Norway by Raufoss using brass purchased from FN.

Fabrique Nationale offers a couple PIE designs of their own. The first is called APEI 169 and is essentially a copy of the Raufoss configuration. It has a Silver/Yellow or Yellow/Silver tip color code, and it may in fact, be built by FN. Also offered is the HEPI projectile (High-Explosive Piercing-Incendiary) in .50-caliber. The Silver/Green color coded HEPI projectile is of a different internal construction, but still PIE in nature. It has a greater fragmentation effect than the Raufoss/APEI design (60 vs. 20 fragments per impact). Fabrique Nationale fifties bear an FNB case headstamp, and both designs are ballistically identical to the M8 API.

The final cartridge of the PIE family is the Raufoss NM160, MPT (Multi-Purpose, Tracer). Carrying a color code of Green/Red, it is the same design as the earlier NM140, but with a small tracer element in the projectile core. They reportedly carry a case headstamp of RA.

The Color Codes

While I can't find anyone who knows for sure, I suppose the Green tip color coding refers to these rounds' Hi-Explosive capability. In the past, Green has been used to designate everything from green tracer, to tear gas, to multiple projectile loadings as well as Hi-Explosive. Yellow has been traditionally used to



The projectile of the Mark 211, Mod-0 cartridge

COLOR CODES		COUNTRY		NOTES
TIP COLOR	HEADSTAMP			
Light Green	EMZ 79	Norway		Raufoss NM140 loading in Norway on Dutch brass.
Light Green	IVI 84	Norway		Raufoss NM140 loading in Norway on Canadian brass.
Light Green	LC 81	Norway?		Probably Raufoss NM140 loading in Norway on US Lake City brass.
Light Green	RA---	Norway		Raufoss NM140 loading in Norway on Raufoss Brass. (Existence is reported, but not confirmed).
Light Green	12.7x99 SB 84	Norway		Raufoss NM140 loading in Norway on Spanish brass.
Dark Green	WCC 84	US?		Possibly one of the OLIN license built NM140 rounds.
Yellow	WCC 85	US		OLIN/Winchester WALAP PIE design.
Green/Silver	50 FNB 91	Norway		Raufoss NM140A1 (US Navy Mark 211, MOD-0) loading in Norway using FN brass.
Green/Silver	HXP 89	Norway		Raufoss NM140A1 (US Navy Mark 211, MOD-0) loading in Norway using Greek brass.
Green/Silver	LC 92	Norway?		Reportedly Raufoss NM140A1 (US Navy Mark 211, MOD-0) using US supplied brass.
Green/Silver	WCC 87	US?		Possibly one of the OLIN license built NM140A1 rounds.
Green/Red	RA---	Norway		Raufoss NM160 Multi-Purpose Tracer loaded in Norway on raufoss brass.
Silver/Green	50 FNB 87	Belgium		Fabrique Nationale design HEPI.
Silver/Yellow	50 FNB 86	Belgium		Raufoss design APEI 169 from Fabrique Nationale.
Yellow/Silver	50 FNB 84	Belgium		Raufoss design APEI 169 from Fabrique Nationale.

indicate Hi-Explosive-Incendiary (HEI) loadings. Since Silver is the traditional tip color used to indicate API, a Green/Silver (or Silver/Green) tip color code would mean Armor Piercing-Incendiary with Hi-Explosive capacity. The Yellow/Silver (or Silver/Yellow) tip color code would mean API with Hi-Explosive-Incendiary capacity. Although the latter seems a bit redundant.

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The Mark 211, Mod-0 cartridge is just one of the two new cartridges in the .50-caliber lineup. The next hotrod is the M-903 SLAP and the M-962 SLAP Tracer. The SLAP round is a special steel penetrator that requires a special barrel of its own to shoot because it requires a radically differently twist rate to correctly stabilize it. The following article is on the different small arms SABOT designs that are pertinent to Hard-Target Interdiction. Some of the other stuff (7.62, wildcat .50-caliber and larger than .50-caliber) is included for historical reference and for heavy-class guns other than .50-caliber.

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.50 CALIBER SLAP AND OTHER DISCARDING SABOT AMMUNITION

by Keith Pagel

A few issues back, I wrote an article about the Raufoss .50 BMG Multi-Purpose and other HE cartridges as just one example of the three "exotic" fifties adopted by the U.S. military. This article is about the second of those three; the .50 BMG caliber SLAP round. As you might imagine, discarding sabot ammunition didn't start with caliber .50. Actually, it's more popular in military circles with larger caliber applications; 20mm and up. Small arms ammunition is not known for its inherent ability to penetrate "hard targets." Since that's the forte of large bore munitions, discarding sabot designs are more prevalent there. While the focus of this article is on the .50-caliber, I'll also discuss discarding sabot ammunition in the other calibers. This is to give you an idea of where .50-caliber fits in the grand scheme of things.

Discarding Sabot: The Concept

For those of you not familiar with discarding sabot, let me first give you the background. Discarding sabot is essentially a way of firing a projectile significantly smaller in diameter than the gun barrel bore. Now why would you want to do that?



Close-up of the .50 BMG caliber, M903 sabot light armor penetrator "Ball" projectile (left, amber plastic sabot) and the .50 BMG M962 SLAP Tracer projectile (right, red plastic sabot). Like the projectile of any discarding sabot design, it consists of two parts: the sabot itself and (center, M903 "Ball") the penetrator. (Photo by Eric Williams.)

Several reasons, actually. In comparison with a standard, full-bore sized projectile, a DS projectile can potentially obtain one or more of the following:

- Higher muzzle velocities.
- Less air drag.
- Flatter trajectories (less ballistic arc, which will require less scope elevation adjustment, etc.).
- Shorter time of flight (which means less wind drift susceptibility and it's easier to hit a moving target from a moving platform for military uses, etc.).
- A lower chamber pressure, if desired. (A DS design is usually lighter than the standard projectile.)
- Less barrel wear. (A sabot is usually made of softer material than the standard full-size projectile.)
- Less recoil (meaning a faster recovery time after firing for civilian shooters, higher rates of fire for you military clients).
- Maintaining projectile integrity. (Trying to move a standard projectile faster and faster eventually means tearing it apart.)
- More mass over a smaller impact area greater penetration. (Even though she weighs much less, there is more force exerted under a woman's high-heeled shoe, than under an elephant's foot.)
- More flexibility per weapon. (The ability to tackle different targets by switching ammo instead of weapons.)
- Some ammo weight savings (important in military applications).

So just what is "Discarding Sabot?" For purposes of clarity in this article, I'll adopt the following terminology: The Projectile is that portion of the ammunition designed to be propelled down the weapon's bore and out the muzzle. In the DS arena, it consists of two portions. The Sabot, which is designed to be discarded early in the ballistic trajectory, and the Penetrator. Unlike the sabot, the penetrator is that portion of the projectile designed to impact a target and consists of either a spin-stabilized Slug, or a fin-stabilized Flechette.

The "sabot" (pronounced SAH-bow and which means literally "wooden shoe") has a maximum outside diameter that matches the inside (or bore) diameter of the barrel in question. The "penetrator" which, being significantly smaller in diameter than the bore, rides inside the sabot until both exit the muzzle. Once free of the barrel confines, the sabot falls away leaving the penetrator to carry on to the target.

The sabot is the key to the design. Without the sabot, there wouldn't be any discarding sabot ammunition. (It would be just another slug traveling down range.) Without the sabot, the firing of fin-stabilized penetrators would be virtually impossible. The sabot's role, while traveling down the barrel, is to provide four basic services. The sabot:



Push-Me-Pull-U: A close-up of some of the discarding sabot designs. Pusher/puller sabots, spin/fin-stabilized penetrators, and their cartridges. Left to right: 5.56 caliber FMJBT M193 Ball projectile. Remington .223/.30 caliber Accelerator spin-stabilized projectile. .308 Remington Accelerator cartridge. 5.56 AAI Advanced Combat Rifle cartridge candidate. The AAI/ACR sabot petals, retaining o-ring and fin-stabilized flechette. 7/.62 NATO caliber Winchester XM948 SLAP. A standard 7.62 caliber FMJBT M80 Ball projectile, and the .50 BMG caliber Winchester M903 SLAP projectile. (Photo by Apex Photographic, Copyright 1994.)

- Transports the penetrator.
- Provides a good gas seal between the sub-caliber penetrator and the bore walls.
- Keeps the penetrator centered, pointed in the correct direction, and maintains the proper angle.
- Aids penetrator ballistic stability. (In the flechette designs, the sabot protects the fins from damage. In the slug designs, the sabot actually provides the stability by engraving the rifling and imparting spin to the penetrator.)

In addition, while still in the cartridge case, the sabot:

- Retains the smaller diameter penetrator in the cartridge case mouth. And by its carefully selected shape and construction, permits the ammunition to be fed into the weapon.

Sabots come in many materials; plastic, fiberglass, nylon, Teflon, magnesium, aluminum, brass, etc. What they all have in common is being a light material that will have a high air drag coefficient. Sabots can be generally classified as either a “pusher” or a “puller.” Basically, either the sabot is behind the projectile (or around its center of mass) pushing it out the bore as the gas expands, or is in front of the projectile pulling it down the barrel. There are also combinations of the two concepts. In the case of a puller sabot, the restraining forces of the bore (plus the pressure of the gas) combine to force it to grip and pull the projectile along.

If a pusher sabot is behind the penetrator, the cartridge case length may have to be made longer to allow for the increased overall length. But, as a sort of trade off, the puller design is tougher to make work. Once free of the barrel, the sabot must cleanly and quickly fall away to allow the penetrator to continue on its course. This action (called “stripping”) can be accomplished in, generally, three ways. In the case of a spin-stabilized penetrator, centrifugal force alone can cause the sabot to come apart once it’s left the confines of the barrel. In the case of a fin-stabilized penetrator, it must be the force of air drag. (At normal RPM’s you can’t spin a fin-stabilized penetrator.

The spinning fins create terrific air drag and then there is the problem of long rod gyroscopic precessional yaw. But more on this aspect later.) In the case of a spin stabilized penetrator, it can be a combination of both air drag AND centrifugal force. An otherwise aerodynamic sabot can be made high drag by the spinning forces, resulting in the required stripping.

There was a fourth technique that was tried on the abandoned SPIW project. (See below) This involved a puller sabot that was designed to stay intact until it passed through a special stripping device. This “stripper” was mounted on the outside of the barrel right at the muzzle and had a striking resemblance to a thread die. It was essentially a block of metal, the hollow center being lined with teeth. As the sabot/penetrator exited the barrel and passed through this, the teeth serrated the sabot allowing centrifugal and air drag forces to peel the sabot pieces away. The drawback was that the inevitable wear on the stripper made it less and less effective. This approach was tried only because of the difficulty encountered in making such tiny sabot components to the high degree of manufacturing tolerances required to reliably function.(1)

As mentioned, the penetrators come in two basic designs; those that are spin-stabilized (generally requiring a rifled barrel bore) and those that are fin-stabilized (generally requiring a smooth barrel bore). The fin-stabilized penetrator is usually known as a flechette (pronounced “fla-SHET,” and meaning little arrow). Spin-stabilization requires a rifled bore, or at least a rifled sabot for firing in a smooth bore. Unlike the sabot, the penetrator is usually made of the heaviest material available. As a general rule, higher density leads to better penetration.

So if the discarding sabot concept has so many advantages, why aren't all projectiles of this design? As you'll see below, depending on the circumstances, there can be some significant drawbacks to a DS design:

- The smaller flechettes don't buck brush as readily. They are prone to being bent which reduces their stability and range.
- The rifling twist rate that's ideal for a full size projectile may not be suitable for the smaller, lighter sabot/penetrator.¹⁴
- Although sabot penetrators are almost always faster than their full-bore cousins, faster doesn't always translate into better.
- Some of the fin-stabilized penetrators will tend to weather vane (turn into the wind), which can affect grouping.
- Designing a successful DS design frequently means dealing with semi and full-auto feeding difficulties in the weapon, i.e.; tinkering with sabot shape and length. An obstacle not as severe when dealing with conventionally projectiled ammunition.
- Then there are the problems of pinning down the most viable sabot construction materials and design, while still maintaining consistent stripping functions. (You're trying to simultaneously design TWO "bullets" for your ammunition, rather than one.)
- In the smaller caliber DS designs, it's much more difficult to control the manufacturing process (and more expensive) than in a conventional projectile design, i.e.; minute manufacturing tolerances required, higher rejection rate, more production steps, etc.
- DS designs aren't useful for most aircraft guns. The sabot pieces can easily be sucked into a jet engine or struck by a propeller, causing considerable damage.

CAUTION: DO NOT FIRE ANY STYLE SABOTED AMMUNITION IN A WEAPON FITTED WITH A MUZZLE BRAKE, COMPENSATOR, FLASH HIDER, OR SHOTGUN CHOKE, UNLESS YOU ARE SURE THAT THEY ARE COMPATIBLE.

Sabots are designed to strip away within a few feet of the muzzle. In most cases, this process begins immediately upon exiting the muzzle. (Right about where your muzzle brake/flash hider would be.) Debris can lodge inside, obstructing the next projectile with severe consequences, or it can cause the muzzle device to be forcibly ripped away from the weapon. From personal experience, I had a Ruger Mini-14 equipped with an M14 style flash hider. The first round of conventional Ball ammo I fired nicked the hider upon exiting, flinging it down range. Fortunately, the only damage was to the rifle bluing. It could've been much worse.

Some Sabot Cartridges

SPIW: An experimental flechette concept started in the early 1960's, and intended to be the future infantry rifle/light machine gun. During the lifetime of the project, four competing designs were tested. The first generation consisted of two designs. The first of these was the AAI manufactured XMI 10. A 5.6x53mm cartridge, developing 4820 fps, and featuring a unique piston primer concept; wherein ignition gases would force the primer back against the firing pin, cocking the weapon. The other first generation design was the Springfield Arsenal XM 144. This was a 5.6 x 44mm cartridge, developing 4585 fps and with a conventional primer. The second generation designs were the XM216; a 5.6 x 44mm cartridge (a fat-case

version of the XM 144) from Springfield/ Frankford Arsenal, developing a muzzle velocity of 4600 fps, with firing rates from 700-1700 rounds/ minute, and conventionally primed. The other second generation design was the XM645; a 5.6x57mm cartridge from AAI firing 600-2500 rounds/minute, at 4820 fps, and piston primed.

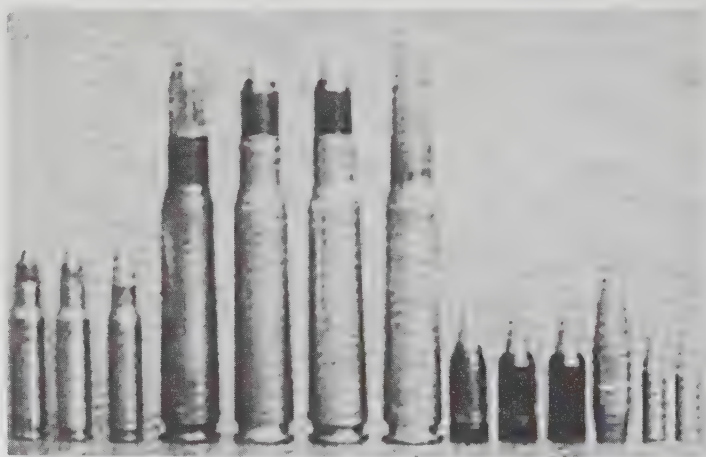
The SPIW project was eventually abandoned due to political pressure over spiraling development costs. There were high speed feeding problems, deteriorating accuracy due to the muzzle stripper, manufacturing difficulties with the flechette and sabot, unreliable stripping of the sabot, as well as conflicting and sometimes contradictory military requirements on the weapon/ammo. This resulted in a design overly complex which, in turn, led to expensive and time consuming development work.(1) The AAI XMI 10 and XM645 designs used brass cases from the Dominion Arsenal of Canada (DA) and Val Cartier Quebec, Canada (IVI) The XM216 and predecessor XMI44 were manufactured using U.S. (FA or RA) cases. All models used the same flechette/sabot pack from AAI; a 10 grain flechette with fiberglass (green) puller sabot.

Remington Accelerator:¹⁵ First introduced in 1979(8), a 52 grain .22 caliber soft point bullet is loaded in a six-petal, tan plastic, pusher, sabot (total weight 64 grains). Some calibers reportedly use an 80 grain .25 caliber soft point bullet instead. Intended as a means of utilizing big bore (.30 caliber) weapons on varmint-sized targets, accuracy isn't quite as good as military specs. (2 degrees, 15 minutes of arc, vs. Milspecs of 1 degree, 15 minutes of arc.)(8) Available in 30-30, .308, and 30-06 calibers originally, some of these loose projectile packs have turned up on the open market for reloaders.

Private individuals have experimented with these in .30 Carbine and 7.62x39 caliber loadings. Headstamped "R-P 30-30 WIN" the Accelerator specimen in Photo #4 is listed at 3400fps muzzle velocity.(10) The standard 30-30 has a m/v of 2300 fps. Headstamped "R-P 308 VIIN." The Accelerator is listed at a muzzle velocity of 3795 fps(8), vs. the (146 grain) 7.62 NATO M80 Ball at 2818 fps.(11)

OLIN/Winchester SLAP: Available in 7.62 NATO (.308) and .50 BMG, both Ball and Tracer. The .50-caliber SLAP is designated M903 in Ball and M962 in Tracer. A Spotter-Tracer (with a zirconium penetrator tip) version was tested as well as loadings in aluminum, rather than brass, cases. The projectile is seated just far enough in the case mouth to obtain an acceptable crimp, since the propellant charge consists of a whopping 275 grains of WC856 Ball powder.

The four-petal sabots are of a hard plastic, pusher construction; with or without crimping cannelures, and are known in colors of amber (Ball), red (Tracer and Spotter-Tracer), white, and green. (The latter two during the developmental phase only) A spin-stabilized design, the .50 SLAP



The Olin/Winchester SLAP family of APDS cartridges. Left to right, the 7.62 NATO caliber cartridges XM948 SLAP, XM959 SLAP-Tracer, and a standard M80 Ball (for comparison). The .50 BMG caliber cartridges M903 SLAP, M962 SLAP-Tracer, experimental Spotter-Tracer prototype, and a standard M33 Ball (for comparison). The projectiles of the .50 BMG M903 SLAP (amber sabot), M962 SLAP-Tracer (red sabot), experimental prototype Tracer (black sabot), and a standard M33 Ball (for comparison). The spin-stabilized penetrators of a .50 BMG M903 SLAP and M962 SLAP-T. Note the sabot and penetrator difference. (Photo by Apex Photographic, Copyright 1994.)

penetrators are a tungsten alloy, .30" (M903) and .33" (M962) in diameter, 1.45" and 1.65" long (Ball and Tracer, respectively), and weigh around 355 grains apiece; while the sabot/penetrator packages (combined) are around 415 grains each. Government cost is reportedly less than \$7.00/round. By comparison, standard .50 BMG M33 Ball projectiles weigh in around 665 grains. Price per .50 BMG Ball cartridge: \$1.17. (11)

Milspecs on the .50 SLAP round state a sabot strip within 50 yards of the muzzle, trace illumination beginning at 300 and out to 1500 yards, a maximum impact dispersion of 18 inches at 600 yards,¹⁶ and a minimum armor penetration of .75" HHA 500 BHN nominal armor plate at 0 degrees obliquity at 1500 yards.(7) Also, maximum average chamber pressures of 55,000 PSIG and an average muzzle velocity of 4000 fps (+/- 50 fps) both at 68 deg. F.(7) By contrast, WW2 issue .50-caliber M2 AP ammo has a maximum dispersion specification of 10" at 600 yards, armor penetration (RHA 350 BHN) of .3" at 0 degrees obliquity at 1500 yards, and with an average muzzle velocity of 2935 fps (at the same chamber pressure).(9) CAUTION! The .50 BMG caliber SLAP designs have been certified for use only in the M2 (BB) weapon at present.

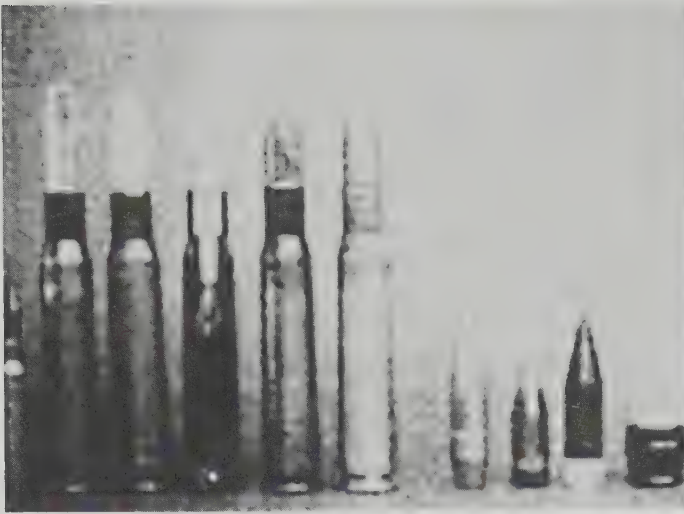
The M962 SLAP-T is also used as an in-bore, sub-caliber, training round for the U.S. Army's 105 and 120mm M1 Abrams tank guns.(5) Developed at the request of the Armament Research Development Command, the "... device consists of a rifle type bolt action receiver group attached to an M2 .50-caliber heavy machine gun barrel, inside a dummy 105mm cartridge case."(5) This sub-caliber device was already in use to fire .50-caliber M20 APIT ammunition in the tank's main gun, which simulated (out to 1200 meters) the accuracy, impact signature, and ballistics of the full size 105mm M393A2 BEP-T round.(5) The .50-caliber M962 SLAP-T is a ballistic match to the 105mm M456AI HEAT-T round out to 1500 meters.(5) Advantages to sub-caliber use:

1. Usable on 112 scale ranges (less danger of overshoot so they can be used on smaller ranges).
2. The unit is not required to deploy elsewhere for training sessions.
3. Replicates all main gun firing functions, practice in handling differing types of ammo in a firing situation, practice changing of fire control computer settings, etc. And
4. Is cheaper at \$7-\$12 each vs. \$250-\$1,000 each(5) for the full-sized rounds.

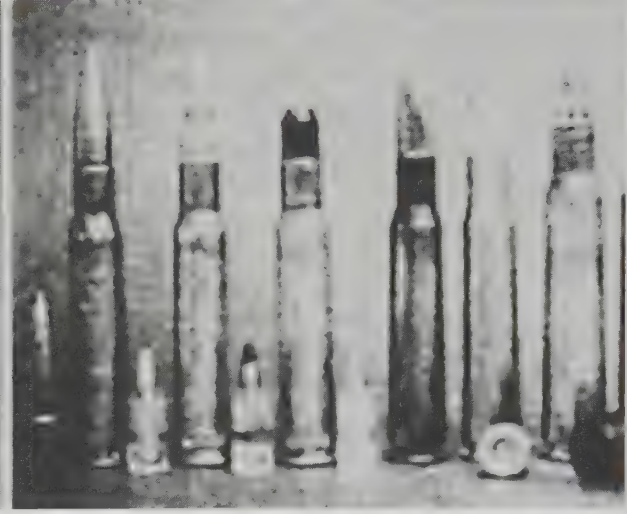
The .50 SLAP specimens pictured here are headstamped "9 WCC I SLAP" (Ball) and "WCC SLAP" (Tracer).

The 7.62 NATO caliber versions of the SLAP are known as the XM948 (Ball) and XM959 (Tracer). While the XM948 Ball round is similar in construction to its .50 BMG cousin (except for size); the XM959 Tracer is simply a 5.56 caliber, M196, Tracer bullet held in a specially modified plastic sabot. (The relatively small size of the 7.62 NATO SLAP penetrators, precludes them from holding any significant amount of tracer compound.) The 7.62 caliber SLAP sabot/penetrator is .86" long, compared to the 7.62 M61 AP bullet which is 1.28". Both the SLAP and SLAP-T utilize a four-petal, amber plastic, pusher sabot design.

Muzzle velocity is listed at about 4000 fps versus 2750 fps for the 7.62 NATO M61 AP(2), and armor penetration is listed as 3/4" RHA at 300+ meters while the M61 AP can only manage about 1/3" RHA at 100 meters. CAUTION ! The 7.62 NATO caliber SLAP designs have been certified for use in the M60, M60E3, and N1240 machine guns as well as the M134/GAU2B Mini-Gun only! The specimens illustrated in this photo are headstamped "8 WCC 5 SLAP" (Ball), and "9 WCC 0 SLAP" (Tracer). (Footnote: To save all the readers a phone call; No, Winchester will not be making any of the SLAP calibers available for sale to civilians.)



The .50 BMG caliber discarding sabot designs. Left to right: The 7.62 NATO caliber DUDS cartridge (for comparison). TRW APFSDS DUDS, Colt APDS, AAI APFSDS, OLIN/Winchester M903 SLAP, and a standard M33 Ball cartridge (for comparison). The projectiles: Standard M33 Ball (for comparison), amber sabot M903 SLAP, black sabot PATEC and orange sabot 20mm Phalanx APDS (for comparison). (Photo by Apex Photographic, Copyright 1994.)



The commercial .50 caliber (spin-stabilized) discarding sabot designs. Left to right, M33 Ball projectile and cartridge (for scale). Maadi-Griffin .30/.50 clear sabots with: 150 gr. Winchester silver tip, 147 gr. Winchester FMJBT, 168 gr. M2 (black tip) AP, and 150 gr. Nosler Ballistic (green) tip in both black and clear sabot. M903 SLAP (for comparison). Williams/RVO, 458/.50 sabot Maadi-Griffin .30/.50 clear sabot 12.7x108 (12.7 Russian) caliber, black/red tip B32 API 12.7x108 for comparison. (Front row) Sabot loading tools from J&D Components. (12.7 Russian specimens courtesy of Bright Ideas. Photo by Apex Photographic, Copyright 1994.)

.50 BMG DUDS: Vietnam era experimental by TRW Corporation. This depleted Uranium flechette design was found to have limited additional armor penetrating qualities over standard .50 BMG AP ammo, but was promising in its ability to penetrate thick concrete obstacles. Developing 4450 fps in muzzle velocity, it featured a clear plastic, three- petal sabot, enclosing a fin-stabilized flechette. The weapon itself is based on a Soviet, bolt-action, anti-tank gun of early WW2 vintage. It weighed 27 pounds, was over six feet long, bipod equipped and had a 48 inch, smooth-bore barrel. Magazine fed with a five round capacity, it had only a six power telescopic sight(12) as well as a primitive (by today's standards) muzzle brake. The cartridge specimen illustrated in Photo #6 is a standard .50 BMG brass case, with a percussion primer, and headstamped "LC 68."

.50 BMG Colt APDS: Circa 1971, this experimental features a 447 grain, 1.5" long, .30 caliber, steel, spin-stabilized, slug for a penetrator. It is probably tungsten-carbide due to its low magnetic signature.(10) The sabot is of two piece, white plastic construction. The specimen illustrated is loaded in a standard .50 BMG brass case, percussion primed, and headstamped "SL 4."

.50 BMG PATEC APDS: An experimental by the Pacific Technica Corp. Santa Barbara, California; the spin-stabilized penetrator in this design bears a strikingly similar appearance to those used in the Winchester .50 SLAP cartridges. These were loaded in standard .50 BMG brass cartridge cases headstamped "M 73", utilized percussion primers, and are known in both white and black plastic three-petal sabots, with an aluminum and clear plastic base. The penetrator is .31" in diameter, 1.55" long, and weighs 351 grains.

Overall weight of the sabot/penetrator package is 430 grains. (Specimen courtesy of River Valley Ordnance.)

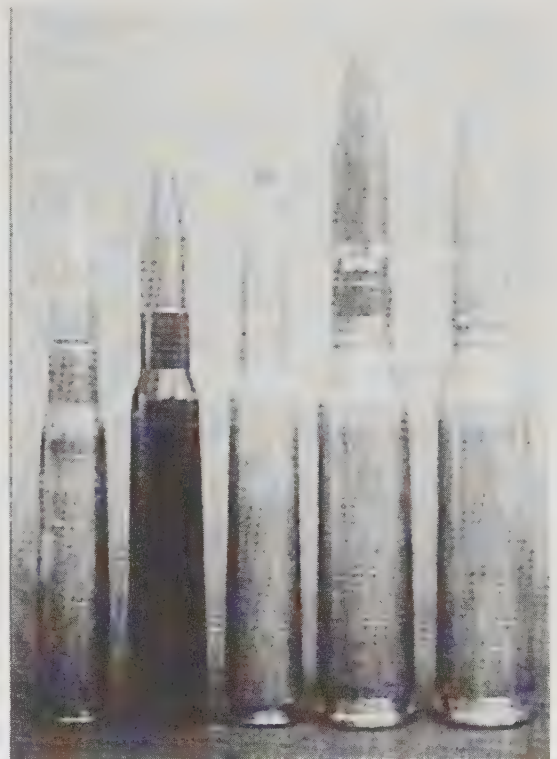
.50 BMG AAI APFSDS: Another experimental by AAI, this is a fin-stabilized flechette design in a three-piece, white plastic puller sabot. To keep the halves of the sabot from sliding fore and aft against each other, they interlock with a unique "lighting bolt" or "zigzag" style seam. Standard .50 BMG brass cases and percussion primers were used. (Specimen courtesy of the Fred Butt collection.).

.30/.50 J&D Components/Maadi-Griffin Sabot: An inexpensive discarding sabot design available from two companies. Available in .22/.30 as well as .30/.50, the sabots are identical except for color. Blue plastic is used in the J&D design with clear or black in the Maadi-Griffin design. Both are a six-petal, pusher sabot of approximately 38 grains. Designed to accept most any .30 caliber bullet, the specimens illustrated include a 165 gr. .30 cal AP (Black tip), a 180 gr. Winchester Silver Tip, and a 180 gr. Nosler Ballistic Tip (Green tip). One of the advantages to this design is a reduction in the overall cost for a .50 BMG projectile. Where most of the full-bore designs cost \$.75 or more, the .30/.50 sabot design costs (depending on projectile selected) as little as \$.35 each. Being spin-stabilized as well, the main drawback to this design (at present) is that the rifling twist rates for most .50 rifles are set up to stabilize the long 650+ grain projectiles and don't do such a good job on these short, light ones.

.458/.50 Williams/Owsley-RVO: A joint effort by Eric Williams of the FCSA and Tom Owsley of River Valley Ordnance, this is an attempt at creating a more suitable hunting projectile for the .50 BMG case. It features a spin-stabilized, sabot, .458 caliber, 400 gr. hollow-point bullet (Barnes X) in a 30 gr. white, one-piece plastic, pusher sabot. Muzzle velocity out of a 29" barrel is around 3450 fps.

12.7x108 Chinese APDS: Exported by NORINCO, this design is reported to be Mainland China's 12.7 Russian caliber competitor to Winchester's SLAP design. Featuring a brown lacquered steel case and a three-petal, black plastic sabot (very similar to the PATEC design), the illustrated specimen is headstamped "41 85". A spin-stabilized design, muzzle velocity is reportedly 3795 fps. A standard Russian 12.7x108 is also illustrated for comparison. It is a black/red tipped B32 API, brass cased, headstamped "3 * * 50" and has a listed MV of 2800 fps.

15.5x106 FN APDS: Intended by Fabrique Nationale of Belgium to be the replacement for the .50 BMG class of Heavy Machine Guns, this caliber was abandoned due to a lack of interest in fielding a new caliber and weapon following the collapse of the Soviet Union. Developing a muzzle velocity of 4420 fps(6), the APDS version of this cartridge features a black, four-petal sabot, with white ink stamping "15.5x 106 APDS." It is brass cased, without



Foreign heavy machine gun discarding sabot designs. Left to right, Standard .50 BMG caliber M33 Ball (for comparison). Norinco (mainland Chinese) exported 12.7x108 (12.7 Russian) caliber, spin-stabilized, APDS and black/red tipped B32 API (for comparison. Belgian FN manufactured 15.5x106 caliber, spin-stabilized, APDS (black sabot, white stenciling) and TP-T (red tip, blue projectile, white stenciling). (Photo by Apex Photographic, Copyright 1994.)

headstamp, and has a brass percussion primer. The conventionally projectiled design also illustrated is a TP-T developing a nVv of 3580 fps.(6) This has a blue projectile with red tip and white ink stamping "15.5x106 TP-T." Like the APDS, it has a brass case, without headstamp, and is brass percussion primed. (Specimens courtesy of the Fred Butt collection.)

20mm Phalanx Olin Ordnance Mk 149 APDS: With a case also known as the 20x102 or 20mm Vulcan(4), this cartridge was developed for the U.S. Navy's CIWS (pronounced SEE-whiz), shipboard, close air-defense weapon. The Mk149 features either a hardened steel or DU, spin-stabilized, slug penetrator (.45 inch in diameter) held inside a four-petal sabot. Fired from a Gatling-gun design, this ammunition sports a sabot of either black, orange, green, or white plastic. The white, dome topped "R2D2-Star Wars" looking CIWS is mounted aboard ship as a last ditch AAIAM defense. The follow-on to this weapon is projected to be the 30mm caliber Goal Keeper system. The Mk149 has a muzzle velocity listed at 3700 fps. By comparison, the M56 HEI series of the 20mm Vulcan (and the M55A2 TP also illustrated) travels at 3380 fps.(2) (Specimens courtesy of RVO.)

20mm AAI APFSDS: Display dummy specimen of an experimental (20 x 102) fin-stabilized, puller sabot design. Using a conventional, brass 20mm Vulcan cartridge case, long rod steel penetrator, and with a white plastic sabot, the label on the round in photo #9 reads: "20mm Armor Piercing Ammunition 385 gr. Steel Projectile 450gr. Sabot Seal Assembly." (Specimen courtesy of the Fred Butt Collection.)

In Closing

This piece was not intended to be the final word on the subject of discarding sabot ammunition. Something of that nature would be outside the scope of a mere magazine article. Some of the designs discussed here, most notably the SPIW, have had whole books written about them. This was just my attempt at introducing you to the concept of DS ammunition and how the .50 BMG caliber fits in.

Numbers in parenthesis refer to the Bibliography section. All photos are courtesy of Phil Abbott at Apex Photographic (Copyright 1994) unless otherwise noted. Cartridge specimens are from the author's collection except where noted. Cartridge case sectioning by Peter Davis. Ordnance consultant: CW2 John Ferry U.S. Army (ret.), Rockwell International. Technical assistance was provided by the Olin Corporation/Winchester Division and Bill Woodin of Woodin Laboratory. The information listed in this article is for historical reference only and not intended as reloading data. Consult the reputable manuals for reloading data.

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Century International Arms P.O. Box 714 St. Albans, VT 05478
Peter Davis LeClair, Davis & Co. 2002 W. 14th St. Houston, TX 77008
HI-Vel, Inc. P.O. Box 340 Delta, UT 84624
J & D Components 75 E. 350 N. Orem, UT 84057
Maadi-Griffin Arms Co. 774 N. 300 W. Spanish Fork, LTT 84660
Tom Owsley River Valley Ordnance Works 3790 Harvester Rd. Harvester, MO 63303
Dave Trowbridge Henry Halverson Olin Corporation Winchester Division 427 N. Shamrock St. East Alton, IL 62024

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AMMUNITION

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While the Mark 211, Mod-0 Raufoss and the SLAP family of cartridges are the more exotic ones, the more common non-Ball round in use is the M-8 API. The Rangers and Special Forces Groups both have M-8 API on their books in 10-round boxes for use with the units' .50-caliber rifles. The Rangers are going to get U.S. issue stuff. The M-8s that the author has seen have all been World War II vintage stuff, the kind with the corrosive primers. Special Forces Groups travel to many foreign countries and conduct training with many foreign conventional and special operations troops. The .50-caliber Sniper Weapons Systems are becoming more and more common in the world these days.

As a result, it is likely that military shooters will encounter some non-U.S. issued ammunition that they will either shoot in their guns or train the host countries' snipers with. As was previously stated in this chapter, many countries produce the .50-caliber cartridges. The U.S. and European manufacture can be relied on to be of high enough quality as to not endanger the operator or damage the rifle. One particular cartridge is the M-8 API as produced in the Dominican Republic. This author has heard some good stuff about the ammo produced there, and a couple of bad points too. Once again the FCSA came through with an article on this very subject.

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SOME NOTES ON DOMINICAN AMMO

by Eric Williams

I've taken notice to some negative remarks about surplus Dominican .50-caliber ammo. Much of this chastising is deserved but, on another hand, some Dominican ammo is a real value in performance and price. My intention is to share my findings on this controversial ammo.

The Dominican surplus ammo began to appear in this country about five years ago, early in 1988. I remember buying it in lots of 300 for 60 cents a round. Gun Parts Co. offered it for as little as 35 cents a round in lots of 10,000. Today, I guess because of dwindling supplies, the price is around \$1.00 a round. The yellow tipped AP rounds make up most of what can be found. I know that Paragon still has some stock of this ammo. There was also a small quantity of pyrotechnical Dominican ammo that came onshore. I have seen the API, APIT, and APT for sale. John Ross (listed in our current suppliers list) still has some stock of the API Dominican ammo for sale. Other than what I just mentioned, the supplies (similar to any other surplus item) are rapidly drying up.

There are a couple of headstamps that can be found among Dominican .50-caliber ammo, and the differences are worth paying attention to. The RD factory code seems to appear on the earlier ammo (55 & 56) while the factory codes were left off on later dates (59 & 60). When you consider the quality of the earlier ammo is much better than the newer dated ammo, it's quite likely the factory code was left off just to cut corners. The difference in quality between the earlier and later date ammo is why it's important to be attentive to the headstamps. The earliest dated Dominican ammo seems to be made with good manufacturing standards. It will typically group around 2 MOA out of most bolt action rifles. With the exception of a few select lots of PMC ammo, the earlier Dominican ammo is as good as any military ammo you will find. I've done some long range plinking with some early white tipped API and have gotten some good results.

While in Montana plinking on a National Guard tank range, I was able to hit an armored personnel carrier at 2000 meters on the first shot using only calculated trajectory tables with the API Dominican ammo. Out of my McMillan M87 the 650 grain API chronographs at 2720 ft/sec while the yellow tipped 700 in AP does 2660 ft/sec. These velocities are right in spec. with U.S. military ammo out of a 29" barrel.

Now, the later dated ammo is another story. Poor standards of manufacture are quite evident with the "newer" stuff. If you shake about one out of four rounds, you can hear the core rattle around in the jacket. Quite often these later dated rounds won't even chamber in your gun because the tolerances were very sloppy on case dimensions and other dimensional characteristics. If you shoot this ammo at a typically sized target at 100 yards, there will be shots that can't even be found on the paper. Because of this propensity to throw some extreme flyers, I've stopped all use of the later dated ammo in my bolt guns.

Unfortunately, there is probably little, if any, of the earlier dated ammo available. The earlier dated ammo that I bought was purchased in 1988 and everything I've purchased since has been junk. I believe that John Ross still has some earlier dated API (white tip) for somewhere between \$2 to \$3 a round. Keep in mind that API ammo is illegal to ship to many states and is illegal in matches. If lucky, you may find some earlier dated AP, but I wouldn't be able to begin to tell you where.

I've also heard that both Barrett and Pauza do not recommend the use of Dominican ammo in their guns. This is another situation like the current ban on Dominican ammo in matches. The whole lot is damned because only some of it is bad. I've gotten perfect



Some Dominican ammo with original box. The two common Dominican headstamps.

functioning in my Pauza with the Dominican ammo if I pay attention to two things. First, as mentioned above, I don't use the later dated ammo, and second, I check all rounds with a profile and alignment gauge. Anything that drops into the gauge and is flush with the base will work fine in any good gun. Unfortunately, these cartridge gauges are scrounged items, currently in short supply.

I've reprinted a couple of letters from the international Cartridge Collectors Journal #3 70, Mar-Apr '93 below. These letters address questions posed in a previous edition about the Dominican .50-caliber ammo, and are answered by some experts on the subject, one being Keith Pagel. Their experience parallels that of mine.

In answer to Q: 369-1, this is an AP made by the Dominican Republic. They manufactured AP, API, and APIT loads in .50 BMG with a confusing variety of tip colors in the latter two. The interesting thing about this ammunition is that the quality deteriorated over time, with many late examples of the yellow-tipped AP having light or no jacket cannelures, sloppy tip paint, poor case mouth crimps, and even loose cores!

As both a cartridge collector specializing in the military .50-caliber cartridges and a member of the Fifty Caliber Shooters Association (FCSA), I'm quite familiar with these specimens. It's a rather typical example of a .50 BMG (12.7x99) "Light Armor Piercing" round from the Dominican Republic. I use the quote marks because the steel utilized to produce these rounds is not very hard. The yellow tip is the DR. code for armor piercing, but in actuality, it won't penetrate any more armor plate than a standard U.S. M-33 Ball round would. In fact, the quality control of the other aspects of this cartridge leave much to be desired as well.

Packaged in flimsy, white, generic looking, 10-round boxes; the descriptive information on the outside is quite often incorrect. A box intended for APIT ammunition, for example, may contain API rounds, with the "trazadores" (tracer) notation crossed off the label.

Also, some shooters of the ammo have reported difficulty in (or the impossibility of) chambering the rounds in their guns. I haven't conducted a scientific sampling, but it appears the custom guns have more trouble in this area than the weapons with chambers made to milspecs, which are more forgiving in their chamber dimensions than the expensive custom target rifles.

Lastly, the tracer varieties (A-PT and APM no longer trace when fired. While I know that it seems absolute heresy to actually SHOOT cartridges instead of COLLECTING them, the Dominican Republic stuff is very popular with the members of the FCSA. (They maintain it makes our ammo more valuable!) It is Berdan primed and apparently non-corrosive. I say apparently since no one has yet complained of it being corrosive. That's not to say that all the possible headstampings are non-corrosive.

While on the subject of headstamps, you might be interested to know that the Texas Cartridge Collectors Assn. published a list of the known calibers and headstamps back in the May/June and July/August 1989 issues of their newsletter. The .50 headstamps fall into three categories. The first has the date at 6 o'clock, arsenal code R at 9 o'clock and D at 3 o'clock, and caliber 50 at 12 o'clock. The second list drops the R D from the headstamp, and the third drops both the R D and the date, leaving only the 50 at 12 o'clock.

The color codings are yellow for AP, Red (actually closer to a reddish-purple or wine) for tracer, and white or silver for API. (White was the original API color code, later replaced by silver.) Known loadings are Ball, AP, APT (yellow/red), APL and APIT (originally white/red, later silver/red).

I mentioned earlier about the popularity of this ammo with the .50 cal shooters. This is

due not only to their abundance, but also to their cheap price. The yellow-tip specimen cited in the original question was originally available by the case at \$.65 a round. Now, they bring about \$1.00 - \$1.20 a round. Even the "exotic" stuff like API, APT, APIT, etc. sells for less than \$5.00 per round.¹⁷

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Prior to the previous reprinted article, it was stated that some of this material is intended to aid trainers overseas that may run into non-U.S. or civilian U.S. manufactured ammunition. Many countries overseas are a bit more dynamic than the U.S. military in their procurement of ammunition. Non military ammunition such as TCCI, PMC and Norinco as well as ammo made in the Dominican Republic and Europe has been encountered by the author overseas. This next article is a limited test that was conducted by two highly regarded members of the FCSA. Two military cartridges and three civilian made cartridges (if you could count Norinco as civilian) were tested.

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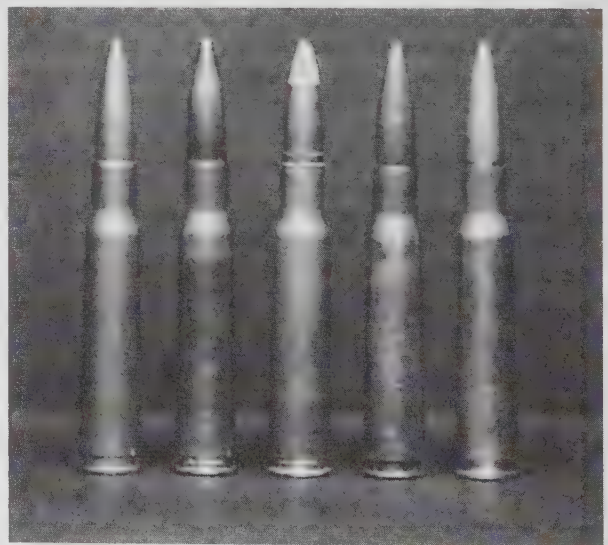
LIMITED COMMERCIAL AMMO TESTS

by Eric Williams and Skip Talbot

As with any firearm caliber and likewise with the fifty caliber, there are more rifles sold than loading dies. Understandably, many do not want to delve into the art of ammunition reloading. For those, in this land of opportunity, loaded ammunition is available on a limited basis.

A lot of attention has been paid to match shooting and ammunition reloading in previous issues. We felt it was important to take at least a cursory look at the quality of some of the available loaded .50 BMG ammunition. With the ability to tailor make handloaded ammunition for each rifle, factory loaded ammunition can only begin to approach the accuracy and quality of hand made ammo. The main reason the average fifty caliber, factory loaded round does not give match level accuracy is because match grade bullets are not generally available in pre-loaded ammunition. This does not mean that you are hopelessly lost in your search for acceptable long-range accuracy if you choose to shoot only factory loaded ammunition. We are aware that at least one manufacturer produces consistent match quality ammunition, and this doesn't take into consideration the custom reloaders. So, how does it all compare?

Before we get to the results of our tests, we need to point out that it is not our intention to prove any order of quality. Our tests are limited and we have not tested all the factory loaded ammunition available. The degree of accuracy will also vary considerably from gun to gun; this will become obvious from our tests. What we will show is that all fifty caliber factory ammunition is not alike and you will most likely have to take your



The rounds used in the test (left to right): TCCI, PMC, Dominican Surplus, Lake City and Norinco.

chances when buying pre-loaded ammunition.

We've entered five different brands of ammunition into our tests. Our tests involved firing 30 rounds of each brand of ammo through two different guns by two shooters. Considering group size, this is not enough samples to give us a strong statistical comparison, but comparisons of velocity and other attributes will be useful. We've measured group size, velocity, bullet weight powder weight, case weight and bullet seating runoff.

Skip Talbot fired half of the ammo through one of his match-quality benchrest rifles at 200 yards out in the Nevada desert, and Eric Williams, shot the remainder through my Harris/McMillan M87 with its oversized bore at 100 yards in Missouri. The data we have collected is presented in the following tables. I have also taken the liberty to calculate the amount of recoil one can expect with each brand of ammo if fired in a Harris/McMillan M87. This calculation is based on the bullet and powder weight, measured velocity, and estimated muzzle brake efficiency combined with an interior ballistics calculation to determine an average powder gas velocity. The calculated value corresponded closely to the actual perceived recoil. I will say something about each brand of ammo so that no wrong conclusions are drawn from the tabular data.

Thunderbird Cartridge Co., Inc. (TCCI) Ammunition

Unlike the other four candidates we tested, the TCCI ammo is remanufactured from once fired U.S. military brass. The only drawback to remanufactured ammo is that you don't know the condition of the brass to start with. This could only be a problem if you plan to reload your fired ammo, since the brass has been fired in a machine gun which is not generally known to have tight headspacing. Although this brass may be somewhat stretched in the web, resulting in poor case life, none of the TCCI ammo which I fired showed any evidence of incipient head separation. Most who buy this ammo won't be reloaders anyway, so it's a moot point.

I checked all the TCCI rounds in a profile and alignment gauge and they all dropped into the gauge as if they were new brass. This means that you shouldn't have any chambering problems with this ammo in any gun. This ammo is also very clean in appearance and it is well constructed. The

Commercial Ammo Attributes

Ammo Brand	Bullet Wt. (grs.)	Powder Wt. (grs.)	Payvelo. Type	Primed Case Wt.	Bullet Total Runout (thousanths)
Lake City 86	647	256	Ball	868	8.62
Norinco 92	690	211	extruded	905	9.64
PMC Lot 5					6.76
PMC Lot 6	657	232	Ball	852	13.01
Dominican AP	706	213	extruded	809	5.68
TCCI remanufactured	748	229	Ball	854	5.19

Bullet, powder, and case weights are the average of three samples. Bullet total runout was measured on a Long Range Specialties gauge 0.92" from the bullet's tip.

Ammo Tests Fired From McMillan/Harris M87 (29" barrel)

Ammo Brand	Velocity Ave. (15 rds.)	Extreme Spread	Muzzle Energy (ft. lbs.)	Average Group Size (3 grps.)	Calculated Recoil w/brake (ft.lbs.)
Lake City 86	2724	74	10663	2.32	30
Norinco 92	2631	82	10608	3.40	34
PMC Lot 6	2687	133	10536	2.68	31
Dominican AP	2643	121	10954	2.26	37
TCCI remanufactured	2682	72	11950	4.34	43

Range - 100 yards; Temperature - 70 F; Barrel Age - 890 rounds; Chronograph - Oehler M35P ten feet from muzzle. All data was collected on the same day alternating through the different brands so as to average out effects from barrel fouling and heating.

quality of construction becomes evident when the seated bullet runout is measured. The average runout was 0.00519", which was the best of all brands tested. I typically get 0.006" runout with ammo that I handload on standard dies. The runout is important because the more a bullet is out of alignment with the chamber when fired the less accurate it will fly.

This ammo is loaded with the same TCCI 750 grain boattail bullet (BC = 0.82) that many match shooters have used. The load is 229 grains of what appears to be T5070. This powder and this charge weight with the 750 grain bullet has been known by handloaders to be an almost magical combination. I used this combination in my own handloads to win the first two FCSA National matches. It is capable of sub-MOA accuracy at 1,000 yards in good rifles. Art Guidi used TCCI factory loaded ammunition to place third in his first National match in 1991.

In terms of muzzle energy, the TCCI ammo is also the most potent of the lot. It outperformed the other brands by a good 1,000 ft.-lbs. of energy in both guns without any evidence of excessive pressure. With the extra energy comes more recoil. After firing 75 rounds of ammo in one sitting, I could easily tell that the TCCI ammo was the hardest recoiling. In pushing the heaviest bullet this is not surprising.

Looking at velocity extreme spread, it was the best ammo in the M87 and the second best in the bench gun. The three groups fired by Skip averaged 2.76" at 200 yards while I got a 4.34' average at 100 yards with the M87. This result needs some explaining. Being that the TCCI bullet is a homogeneous solid, it does not perform well in oversized bores because of its inability to obturate. Harris/McMillan M87 button-rifled barrels start out oversized and they only get worse with age. In fact TCCI ammo carries a disclaimer regarding accuracy and shooting their ammo in Harris McMillan barrels. You can now see why.

In terms of fouling and barrel wear, we did not run enough tests to make any conclusions here, but the general perception is that TCCI ammo does not score well in these categories. I've shot many TCCI bullets over the years and my experience is in line with this perception, but the degree of fouling and barrel wear was not enough to cause me to stop using the TCCI bullets. The accuracy I could obtain with the TCCI bullets more than made up for their fouling and wear characteristics.

Of course, TCCI ammo is only available from TCCI of Phoenix, Arizona. At the time of this writing, TCCI ammo is priced at \$1.98 each in lots of 100. Because of strong recent demand for this ammo, buyers over the last year have been backordered. Of course, how many other shooting related items have been in stock during the last year of turmoil?

U.S. Military Ball Ammunition - Lake City Arsenal

This lot of military ball ammo is quite typical of U.S. military ammo. It does not produce match grade accuracy, but it will do for most plinking jobs. This particular lot of ammo was loaded with a heavy charge (256 grains) of a slow lot of WC860 powder. This high density of loading resulted in the lowest extreme spread of velocities in the bench gun and was equally

Ammo Tests Fired From Talbot Custom Rifle (34" barrel)

Ammo Brand	Velocity Ave. # ft/s	Extreme Spread	Muzzle Energy (ft.lbs.)	Ave. Group Size (# grps.)
Lake City 86	2921 / 6	24	12261	3.67 / 3
Norinco 92	2790 / 7	53	11929	5.46 / 1
PMC Lot 6	2870 / 5	109	12019	2.63 / 1
TCCI remanufactured	2823 / 6	33	13240	2.76 / 3

Range - 200 yards; Temperature - 75 F; Barrel Age - 600 rounds; Chronograph -
Oehler M35P fifteen feet from the muzzle.

consistent with TCCI ammo in the M87. I suspect this is a virtue of the high level of loading density. It was only average in seated bullet runout at 0.00862". This was the highest velocity ammo tested in both guns but in all fairness, it also pushes the lightest bullet, the 647 grain M33 bullet. Because of the light bullet the recoil was also one of the lightest of the candidates we tested.

Over my years of consulting with FCSA members, I've said many times that military ammo typically produces a 2 MOA level of accuracy. This is essentially what Skip and I found with this lot of military ammo. I would also have to put the perceived level of fouling at average with regards to other ammo I have had experience with. There is also nothing exceptional I have noticed about military ball ammo regarding its barrel wearing tendencies over the years I have shot it. This observation also holds true for MU, PMC, and other military ammunition.

I must warn that all of the military ball ammunition that I am aware of is loaded with a steel cored bullet. This can contribute to a ricochet problem, so it is important to take your backstop into account when shooting this ammo. I bring this up because many who pull these military ball bullets are fooled to thinking that they are lead cored by the presence of the lead plug in the bullet's base. This and all other U.S. military fifty caliber ammo is not consistently available. It has been advertised within the pages of the *Very High Power* and the *Shotgun News* or it is sometimes stumbled upon at gun shows.

If I had to guess I'd say that some U.S. military ammo that ends up in civilian hands is smuggled ammo while much is ammo that was retired for demolition that somehow missed its trip to the furnace. Needless to say, U.S. military ammo is not openly sold to the public and one must buy all they can when it becomes available. I can almost guarantee that it won't be available from the same source if you go back after a period of time to buy more. You can usually expect to pay \$1.50 to \$2.50 a round for this ammo when it is available. We did come very close to having Winchester/Olin sell its fifty caliber ammo on the open market. They changed their mind after the political problems they had with their Black Talon ammo.

PMC .50 Caliber

PMC is the first ammunition manufacturer to offer the private shooter new factory loaded .50 BMG ammunition. Over the years, several lots of their .50 BMG ammunition have been sold. I mention this because PMC ammunition quality has varied considerably from lot to lot.

For several years PMC had sponsored a trophy at our National Match. To compete for this trophy the top five shooters at the end of the competition would each shoot a target with PMC supplied ammunition. We witnessed some spectacular groups during this competition. In particular, using PMC Lot 5 ammunition two out of five shooters posted sub-MOA groups at 1,000 yards and the other three shooters were close behind. This kind of precision from factory loaded ammunition is generally unheard of.

On the other hand, a newer lot (Lot 6) of PMC ammo has been found to be sub-standard in quality. Some numbers to support this follows: a sample of Lot 5 ammo averaged 0.00676" in seated bullet runout, while a sample of Lot 6 averaged 0.0130", or twice as much.

Unfortunately, we didn't have enough of Lot 5 to conduct shooting tests with. Between the two guns we averaged about 2 MOA accuracy for this ammo, which is not really bad. The velocity extreme spreads were the worst of all ammo tested. This may correlate with the finding by some shooters of some over pressure rounds from Lot 6. There may have been some very loose tolerances on the powder charges within this lot. We only pulled three rounds to weigh the charges; thus, we weren't able to obtain statistically significant variation data on

the charge weight. The load is a pretty standard 232 grains of a Ball powder identical in appearance to WC860.

This ammo is usually sold for around \$2.50 a round and is packaged 10 to a box and 160 to a case. It is very clean as any new ammo should be. Even with the problems with Lot 6, I still highly recommend PMC ammo. PMC is well aware of the problems with Lot 6 and has made an effort to replace ammo for shooters having problems. The lot on sale now is Lot 8. It has the same factory headstamp (PSD) as good old Lot 5 and, even though we didn't test it I would expect good performance. You can find the lot number on the inside of the box flap. For Lot 6 it would have read 5OA-006. Lot 6 also sported the more commercial headstamp of PMC 50 CAL.

Norinco Ball Ammunition

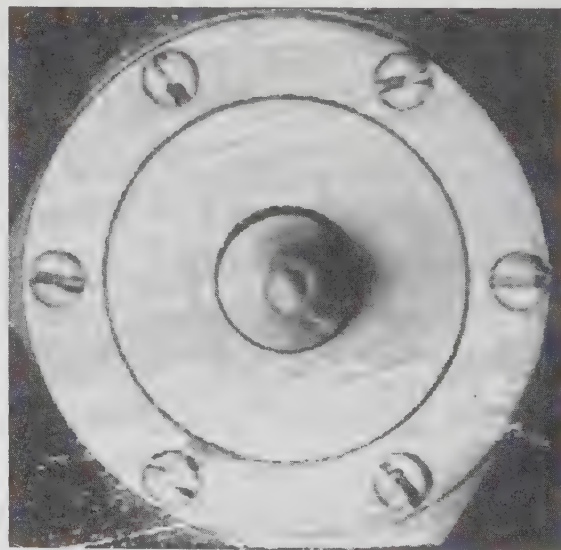
Before this ammo came to our shores I had heard about its existence. I had high hopes that it would offer shooters a cheap alternative for some good plinking ammo, like with much of the smaller caliber ammo Norinco sells. Unfortunately, the price turned out to be \$2.00+ a round, which would be fine if the quality is there, but is it?

There is not much about this ammo that meet the usual specifications for U.S. Ball ammo. The bullet weight is 690 grains. It is loaded with 211 grains of an extruded powder, and the brass case is a bit heavier than usual. While these attributes don't effect the ammo's accuracy, the 0.00964" seated bullet runout will. Both Skip and myself found this ammo to have a 3 MOA level of accuracy. You wouldn't complain if you were feeding a machine gun, but better can be found when feeding your bolt gun. I found nothing about this ammo that could be unsafe or bad for one's gun; its accuracy is just not up to par with the price. I have also punched some spent primers and found some of the flash holes to be off-center. Even with that, the case is reloadable and should last for a good number of reloads. Due to the ammo importation ban from China, supplies of this ammo are dwindling. I'd suggest you buy some soon if you want to keep some plinking ammo in your stock. Defense Technology is the sole distributor of this ammo.

Dominican AP (Yellow Tipped) Ammunition

Since this ammo is generally no longer available these tests are only useful as a comparison to the other brands in the test. (I believe that Paragon still has some small stock of this ammo available) It's also a look into the quality of foreign military ammunition. Here again, as with PMC, there have been several lots of this ammo imported. These tests utilized ammo from the 1956 lot which is known to have been the best lot.

One problem with all lots of this ammo is that its dimensions are on the large side; just barely in spec. If you have a minimum headspace gun you may not be able to chamber it. This is why Skip was not able to run tests on this ammo. My M87 was able to chamber the rounds but some chambered with difficulty. Because this round fires a 706 grain armor piercing bullet, its recoil is a bit heavier than the standard ball round.



This photo shows a round inserted into a profile and alignment gauge. This round suffers from a considerable amount of runout as evidenced by the uneven gap between the bullet and the gauge.

I was surprised to find out that my Harris/McMillan M87 with this ammo produced some of the best groups in the test. It also had some of the smallest amount of seated bullet runout. The other great thing about this ammo was that in 1988 I purchased about 600 rounds of it for only 60 cents a round. I remember at one time Gun Parts Corp. offered 10,000 round lots for only 35 cents a round.

The Dominican brass is Berdan primed and, therefore, is not generally reloadable. I wouldn't recommend reloading this brass even if it were Boxer primed, since it tends to show evidence of age hardening. The evidence is that a few rounds with cracked necks will usually be found in any sizable lot. When you purchase surplus foreign ammo, such as the Dominican, its kind of pot luck as to the quality you will get. When the price is right my recommendation is to buy.

The bottom line is that all pre-loaded .50-caliber is not the same; it differs in a variety of aspects. It is also not consistently available. Both TCCI and PMC have been known to run out of stock. The lesson is that when you find available ammo, buy it. If you want ammo for general plinking I would recommend buying it based on price. If you want to shoot for accuracy, I strongly recommend the TCCI ammo. It has been very consistent ammo over the years and will compete with the best handloads you can produce. Another option is to contact a custom reloader such as McMurdo Bullets or other reloaders found in the Suppliers List. In any event, there are possibilities for non-reloading shooters needing ammo.¹⁸

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PART II: HEAVY-CLASS CARTRIDGES OTHER THAN .50-CALIBER BMG

This brings us to a close on the standard and exotic military cartridges for use in .50 sniper rifles. We have taken a look at the M8, M33 Ball, M20 APIT, Mark 211, Mod-0 Raufoss, and both variants of the SLAP round. In Chapter 1, we took a look at the earlier .50-caliber sniper rifles as well as some other caliber heavy guns. Now we are going to examine the cartridges that some of these guns fired. Not all of these cartridges are obsolete and out of use. Some of the cartridges were used in guns that are the basis for very current weapons (such as the PTRD and the current 14.5mm guns).

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THE "OTHER" FIFTY CALIBER ROUNDS

by Keith Pagel

Many of you would be surprised to learn that the U.S. wasn't the first country to explore the feasibility of producing a gun in .50-caliber. Actually, it was rather late in "joining the club." In fact, many countries were toying with ammunition calibers ranging from 10 to 16mm for heavy machine gun and anti-tank rifle purposes long before America. Some of these experiments even predate World War One. This article is about those "other" .50 cal cartridges. The ones that didn't come from the U.S.

Now this article's purpose is not to turn you all into cartridge collectors. It's to help the reader identify (& subsequently avoid) cartridges similar to .50 BMG when shopping for ammunition. This is due, in part, to some of the ammunition buying horror stories you have shared with me the past couple years. Also, I hope to give you an appreciation of not only where our caliber originally came from, but where it's going.

In defining the limits of this guide, I'm concentrating on heavy machine gun and anti-tank rifle cartridges of the modern era. We're talking about calibers from around 10 to 16mm and

from World War One to date. I selected these criteria since they most closely match those of the .50 BMG (12.7 x 99) round and would, naturally, be of the most interest to the members.

Work on the U.S. .50 was started right after WWI (reportedly at the personal request of General John J “Black Jack” Pershing) and was intended as both a HMG & AT rifle cartridge. The caliber range was selected since the HMG is usually defined as a caliber between 10 & 16mm. And also because cartridges that fall in that range most closely match the .50 BMG in appearance. Hence, they might be encountered & confused with it. These criteria also serve to exclude hunting or sporting cartridges, of a similar caliber, of any era (i.e. wildcats, .50 AE, .458 Winchester Magnum, etc.), as well as military cartridges of a similar caliber without smokeless powder (i.e. musket, U.S. Civil War, Franco-Prussian War, Spanish-American War, etc. ammo). It is not likely that these would be confused with U.S. .50 BMG ammo.

Not all calibers that do meet the criteria will be covered, however. Some are experimentals, others are hard to find. Consequently, its not likely that you’ll encounter quantities of them for sale and confuse them with the BMG cartridge.

The Guide and how to use it. As shown in the example, the first set of numbers at the top/left of each entry indicates the metric diameter of the standard projectile, followed by the metric length of a standard case (rounded off & approximate, there are some slight production variations). Any alphabetic characters immediately following the case length indicates rim type. No letters at all indicate a rimless cartridge, “SR” indicates semi-rimmed, “R” indicates rimmed, & “B” indicates a belted case.

On the same line, immediately to the right, and in parenthesis, are the other names the cartridge is known by. In many cases one moniker of the cartridge will actually be the name of the weapon it was chambered for. (e.g. “.50 Browning Machine Gun” refers to both the weapon and the cartridge.) The same cartridge is usually known by many different names depending on the country of adoption.

The area below the top line marked “Notes,” are the details of the cartridge. You’ll find included here the year and country of origin, purpose (I-IMG, AT, etc.), present status of the caliber (in use, obsolete, etc.), known muzzle velocity (for comparison purposes), projectile types, handling cautions, etc. Scattered through out, you’ll see the numbers one through eight in parenthesis. This indicates the original reference that provided the preceding information. (See Bibliography below). In the area marked Key, you’ll find tidbits of information about the cartridges appearance and construction to help you differentiate it from the .50 BMG round. (See On A Final Note below). In the event that you encounter any of these rounds for sale (or in operations CONUS and overseas),¹⁹ you’ll be better able to avoid buying (or using) something not intended for firing in your 12.7 x 99mm gun. (There have been instances of people mistakenly selling .50 BMG ammo that wasn’t .50 BMG.)

A photograph of each cartridge is also provided. The photos are by Eric Williams and of specimens from his personal collection.



12.7 x 99mm (.50 BMG, .50 Long)

12.7 x 99mm

Notes: Development began in the U.S. starting in 1918 as both as HMG and AT weapon caliber. Earliest specimens were rimmed, later changed to semi-rimmed, and finally rimless cased. Currently under production in the U.S. , NATO, and many third world nations. Select variations in use as a sniper/anti-material round. Muzzle velocity 3100 ft/sec. Loadings include Ball, Tracer, Observation (or Spotter-Tracer, Incendiary-Tracer), AP, Incendiary, API, APIT, APT, APDS, APDST, APHCI and HEIAP.

Key: Majority of cases manufactured in brass and utilize Boxer primers. Some specimens in steel cases or with Berdan primers. Identified by case headstamps (year & source of manufacture) and projectile tip color (type of loading). Pre-NATO British loadings identified by primer sealant.

12.7 x 81SR

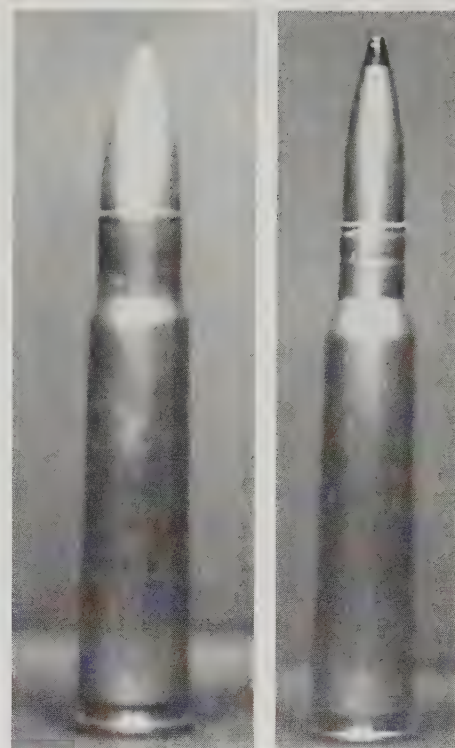
Notes: Developed in 1924 and obsolete by WW2, this cartridge was originally developed by the British as a rimless cartridge (5) for an air-cooled aircraft machine gun. Later adopted in a semi-rimmed case by Italy, Spain and Hungary. (5) Only Italy & Japan made extensive use of it during WW2 including loadings in HE, Ball, AP, Tracer, Incendiary (or Observation-contains White Phosphorus), APT, HEI, APHEIT, (3) API, I-T, HET (5). EXERCISE CAUTION IN HANDLING. Muzzle velocity 2430 fps. Made for export by the British Kynoch Co. (5). Significantly inferior ballistics compared to the BMG.

Key: Case length shorter than .50 BMG, also not much shoulder area, (case neck is only 5mm smaller than case body). Some cases made of lacquered steel, while, Japanese rounds lack case headstamps. Some HE projectiles have brass fuses.

12.7 x 108

Notes: Developed in the late 1920s (6) or 1938 by USSR for ground heavy machine gun use. Rimmed version saw brief use as both HMG & AT cartridge, while rimless cased ammo continues in service today. Most recent weapon chambered is a four-barreled rotary machine gun for the MI-24 HIND attack helicopter (1) MV=2700 fps for conventional projectiles (3) and 3770 fps for APDS projectiles (8). Loadings include API, APIT, HEI (Type ZP WW2 vintage, flat tip-hollow point, air gap fuse, EXERCISE CAUTION IN HANDLING.), Tracer (4), Incendiary, APDS (8) and Ball. Reportedly in use by Hungary as a sniper round²⁰ (7). Adopted by all Warsaw Pact nations as well as many 3rd world nations (China, Africa, Asia, Middle East, etc.) Ammunition even in production for export by France and Belgium (8). Closest to .50 BMG in popularity, ballistics, applications and longevity.

Key: While the U.S. .50 uses a case MOUTH crimp, most of the non-chinese (8) 12.7mm ammo utilizes a heavy double crimp on the case NECK. Most production on lacquered steel cases although brass and brass washed steel have been encountered. Case dimensions similar to BMG, except in greater length. The case is Berdan primed. COMBLOC case headstamps usually consist of two sets of characters: Factory code at the top (12 o'clock position) and year of manufacture at the bottom.



12.7 x 81SR (12.7mm Breda, 12.7mm Type 1, 12.7mm Mod 36, 12.7mm Jap HO-103, .50 Vickers-Armstrong V/565)

12.7 x 108 (12.7mm russian, 12.7mm Soviet Type 54, 12.7mm DShK)

12.7 x 110

Notes: Reportedly "... a British North conversion to a Colt machine gun of pre-World War 1 vintage.(4) If true, this cartridge would not be for a modified .50 BMG weapon, as the .50 BMG didn't even begin life until AFTER WW1. A second variant on this same cartridge exists (But semi-rimmed, rather than rimless). (4) Only one type loading is ever encountered; a rather blunt, round-nosed, ball projectile. Individual specimens are frequently encountered on the collector market, but never widely produced.

Key: With a wider and longer case body than the .50 BMG cartridge, the shoulder area is short and much steeper. Projectile ogive is noticeably different.

12.7 x 120SR

Notes: Appearing to be a stretched version of the 12.7 x 81SR cartridge, this was an attempt to upgrade the ballistics of the .50 inch Vickers-Armstrong

machine gun family. The V numbers designate projectile weight. Developed in Britain in the 1930s and available in Ball, AP, APT (4), Incendiary, Flame and Smoke Tracer loadings. (5) Saw some use by the Japanese. (1) Long ago obsolete in British service.

Key: Except in overall case length, it is strikingly similar in appearance to the U.S. .50 BMG cartridge. It is Berdan primed and offered in very limited number of loadings.

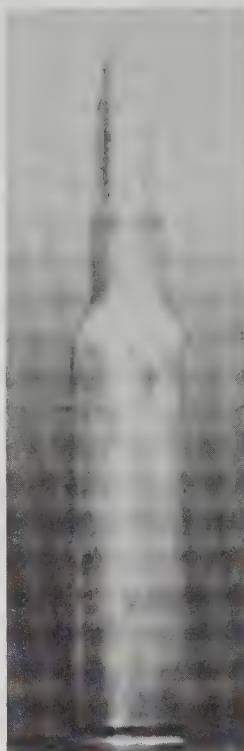
13 x 64B

Notes: Developed in Germany during the 1930s as an aircraft machine gun caliber, later adopted by Japan (6), Finland, Italy, Romania, Switzerland & Spain (5) for the same function. Obsolete by the end of WW2; the standard loading for this caliber was a fused HE round. Also fielded were Tracer, HET HEIT, APT (6), Incendiary (3), API (Phosphorous), I-T, Practice, SD-T, AP, and Ball (5). **EXERCISE CAUTION IN HANDLING.** Muzzle velocity is 2370 feet per second.

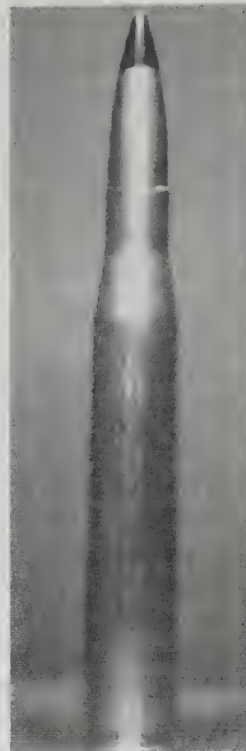
Key: Extremely short for a machine gun cartridge, with a case neck almost the same diameter as the case body. Consequently, very little case shoulder. The presence of a case belt is also a dead giveaway. Casings may be encountered ranging from brass, to copper or brass washed steel. (5) Early versions are percussion primed, later switched to electric priming (3).

13 x 92SR

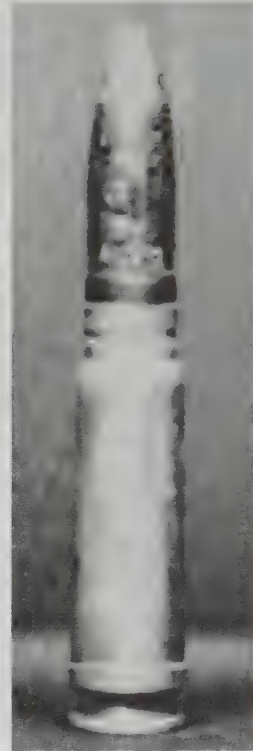
Notes: Developed in 1917 by Germany as an anti-tank caliber. Original weapon based on a scaled up Mauser Bolt action military rifle.(5) It was later to have been for a heavy machine gun



12.7 x 110 (.50 North, .50 Colt-Kynoch M1901)



12.7 x 120SR (.5 Vickers-Armstrong High Velocity, .5 Vickers-Armstrong V664, .5 Vickers-Armstrong V690)



13 x 64B (13mm Soluthurn, 13mm Jap Type 2, 13mm MG 131, 13mm Rheinmetall.)

that never materialized. Only known loading is AP. Muzzle velocity is 2620 fps (4). Now obsolete, but many guns are still in private U.S. collections.

Key: Berdan primed and with a semi-rimmed rather than a rimless case like the U.S. .50. Case shoulder is longer with less taper.

13.2 x 99

Notes: Developed in Britain by Kynoch in the mid 1920s for the Hotchkiss machine gun and obsolete by the end of WW2. (3) Adopted by France, Italy, Japan, Belgium (4), Mexico, Poland, Romania, Chile and China (5). Belgian and French cases have shorter necks, but retain the original overall cartridge length (4). Some ammo produced by Germany for captured weapons (5). Muzzle velocity reported to be anywhere from 2200 fps to 2620 fps (93). Loadings include Ball, Tracer, AP and APT. (5) Some Japanese production in an HE design for anti-aircraft use. (6) EXERCISE CAUTION IN HANDLING. No longer in production. (A

companion round, 13.2 x 96mm, was known as the 13.2mm Hotchkiss Short or 13.2mm Model 1935. Reportedly developed to prevent confusion between the .50 BMG at 12.7 x 99 and the 13.2mm x 99 Hotchkiss Long). (5)

Key: One of the cartridges most frequently confused with the .50 BMG. Except for projectile diameter and the Berdan primer, almost identical to the U.S. cartridge. Case headstamps being another source of identification.

13.9 x 99B

Notes: Developed in Britain during 1935 as an anti-tank caliber (3). Ammunition manufactured in both Canada and the UK, with Ball loadings being the most commonly encountered. AP, Tracer and Practice specimens also exist (5). Muzzle velocity is 2500 fps (4). Obsolete before the end of WW2 as an Anti-tank round, a Breda experimental machine gun was modified to fire this caliber using captured ammo (5). Many of the AT rifles, now rebarrelled to .50 BMG still exist in private collections. Ammunition of the original caliber is still available on the surplus market and can frequently be found in five round stripper clips.

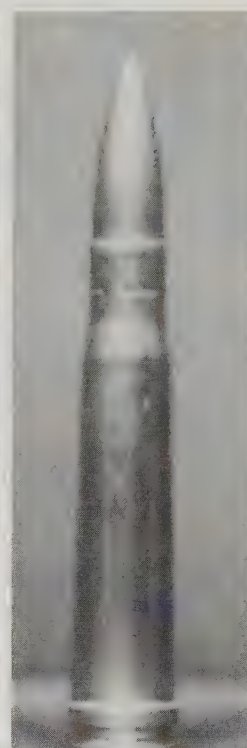
Key: Except for projectile diameter and case belt, closely resembles the U.S. .50 BMG cartridge. It is Berdan primed.



13 x 92SR (13mm
Tankgewehr, 13mm
Mauser, 13mm TuF)



13.2 x 99 (13.2mm
Breda, 13.2mm Vickers-
Armstrong, 13.2mm
Hotchkiss, 13.2mm
Hotchkiss Long, 13.2mm
Jap Type 93, 13.2mm
Jap Type 3, 13.2mm
Model 1930.

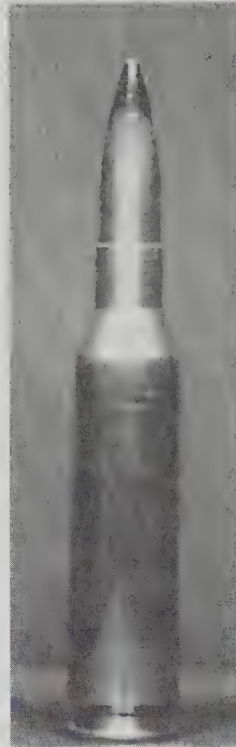


13.9 x 99B (.55 Boys,
14 x 99)

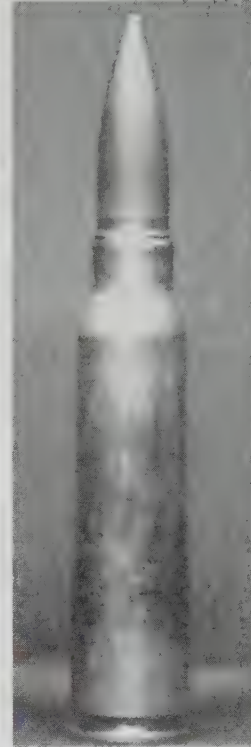
14.5 x 114

Notes: Originally developed in the late 1930s as an AT round, armor advances during WW2 quickly rendered it obsolete (7). Later employed in a heavy machine gun where it continues in service today. Loadings include API, APIT, I-T (7), AND HEI (Type MDZ) (8). **EXERCISE CAUTION IN HANDLING.** In service with the former COMBLOC nations, as well as 3rd world nations of Asia, Middle East and Africa. France and Belgium manufacture the ammo for export (8). Recently chambered as a heavy sniper rifle caliber. The muzzle velocity is about 3200 fps .

Key: The cartridge is Berdan primed. COMBLOC and Chinese production ammo utilize standard headstamping practices. The case material is made of lacquered steel, copper washed steel, brass washed steel, as well as normal brass (5). Overall appearance is that of a scale up fat .50 BMG round.



14.5 x 114 (14.5mm Russian, 14.5mm Soviet, 14.5mm KPV, 14.5mm PTRS, 14.5mm PTRD, 14.5mm Type 56, 14.5mm)



15 x 104 (15mm BESA, 115mm Brno, 15mm Vz 38, 15mm CZ 60, 15mm M1938.



15.5 x 106 (15.5mm FN, BRG-15, 15mm Browning, 15mm Milo, 15mm Brno)

15 x 104

Notes: Developed in 1937 by the Czech Brno company as an antitank machine gun round (4). It also saw some use in Czechoslovakia as an AT rifle cartridge (3). The MNG was later adopted by Britain as the BESA Mk 1. Some German production on steel cases with both standard & short case necks (4). France also produced ammo for export (5). The muzzle velocity is around 2900 fps (4). Loadings include Ball, AP, APT, Short Range (5), Tracer (6), and HET (3) **EXERCISE CAUTION IN HANDLING.** The caliber is now obsolete.

Key: The case is Berdan primed. Most production projectiles have rotating band type areas which may be visible in the loaded case (4). Case headstamps will also aid in identifying cartridges.

15.5 x 106

Notes: Initially designed in the early 1980s as a 15 x 115mm machine gun round by Fabrique Nationale of Belgium, and intended to replace the .50 BMG caliber. (2) It was upgraded and redesigned in 1989 to 15.5mm due to projectile induced barrel wear difficulties (7). The muzzle velocity is about 3440 fps with conventional projectiles, and 4400 fps with APDS ammunition. Loadings include APDS in both Tungsten Carbide and Depleted Uranium penetrators, as well as conventional AP, APT, APHC HEIAP (2) and API projectiles (5). Reportedly it has been cancelled due to shrinking military budgets and a lack of customers.

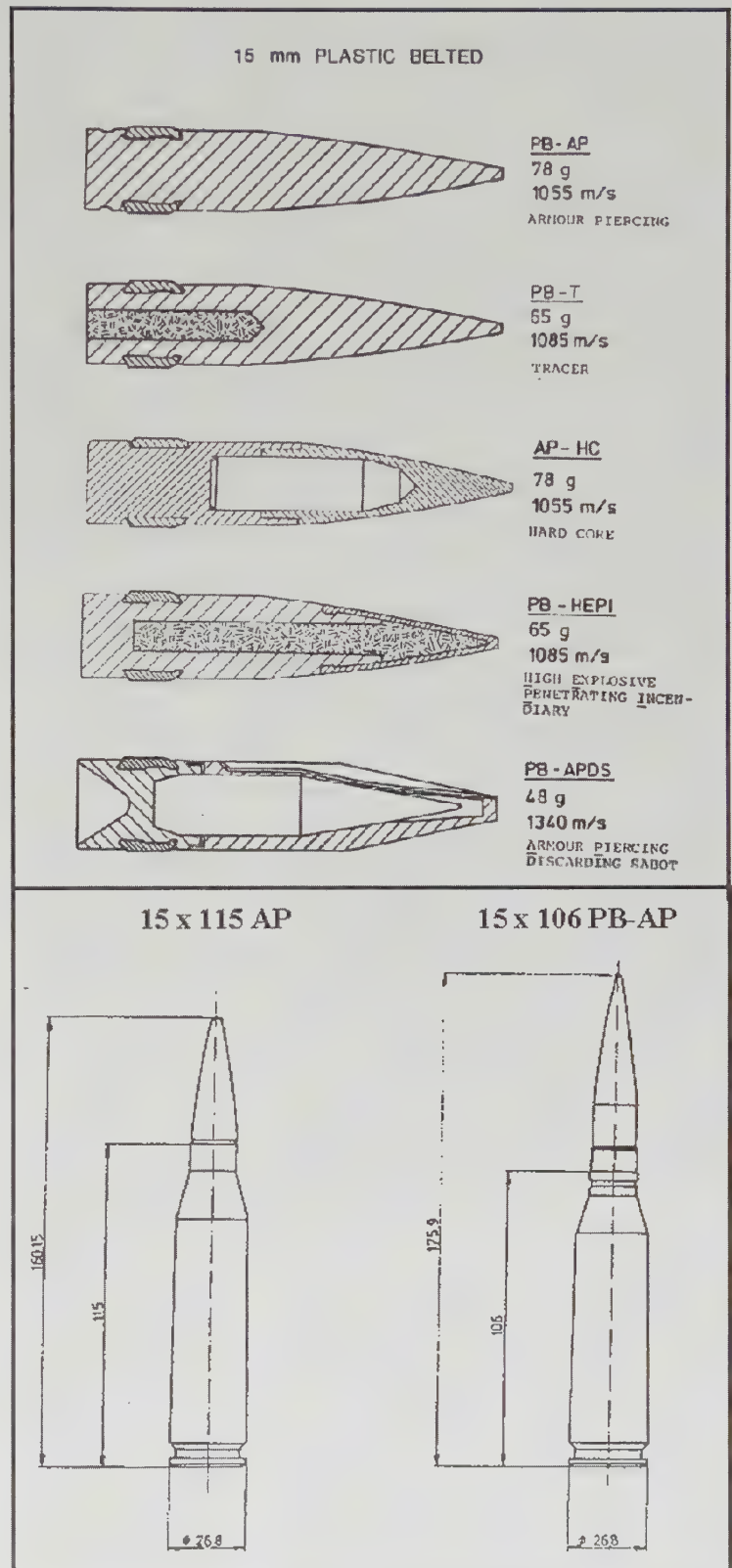
Key: All case specimens examined to date are of brass alloy. Overall appearance is that of a scaled up .50 BMG. All cases either have FN headstamps, or none at all. The case is Berdan primed.

It is this author's opinion that this cartridge had/has the most promise as a heavy-class rifle cartridge of them all, including the .50-caliber BMG. The original 15mm round was a jacketed bullet that cut the rifling much like a conventional bullet does when it passes down the bore of the gun. In June 1987, FN decided to make a radical change to the bullet design to increase barrel life and accuracy. Their options were to upgrade the .50 machine gun or correct the 15mm design. The result was the birth of the 15.5 x 106mm cartridge. The jacketed bullet was replaced with a solid steel bullet (one of a family of bore riders) that had a plastic injection molded driving band around the bullet.

When they switched to a plastic driving band, their barrel life went over 5,000 rounds in the burst fire mode (a rate of 200 rounds in two minutes), with an unlined steel barrel. The change also reportedly increased the penetration capability by more than 60 percent. FN claimed that this cartridge could defeat the same armor as the 20 x 139mm to a range of 1600 meters.

A heavy sniper rifle built using these cartridges would have an extended barrel life and a lower operating pressure than other guns like the 14.5mm which has tremendous overpressure but not too bad on the recoil part.

There has been some rumbling in the sniper community as well as the builders community about the



construction of a gun on this caliber.
Rumor has it that already has been done.
It takes a special destructive devices
license to build a gun on this caliber.

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BULLETS TECHNOLOGY OUTSIDE THE MILITARY

The next major focus of this chapter is on the bullets that go into these large cartridges. We have taken a good look at the military bullets that are in use today. Now we are going to take a look at the bullets that are exclusively developed and used within the civilian shooting community. Again, the Fifty Caliber Shooters Association is given the credit for not only this material but the development of the technology. Many of these special match bullets are CNC lathe-turned bullets that military projectiles have no chance of matching in terms of accuracy and precision.

When we were doing a lot of shooting of the heavy rifles in the military, we noticed that they never did group very well at short range. When we shot the M600 at Fort Bragg at 200 yards, the best we could get was about 3 MOA. Granted, that was with some ratty M33 Ball. When we put a E-shaped silhouette at 1,000 yards (19 inches wide), the guys that could make the gun shoot could easily keep the rounds in the chest area of the target. That's about 1.5 MOA. Within the staff was a discussion about the need for a bullet to go to sleep or settle down some before it could group well. We surmised that because the bullets in the M33 Ball of the time was such trash, they needed a further distance downrange to group well, or go to sleep. The following are responses by well known builders and shooters of .50-caliber rifles. The question was concerning the theory of bullets "going to sleep." The responses are printed in whole here.

Gale McMillan: After firing nearly 20,000 rounds during the M88 contract. It was over 18,000 plus. At both 100 and 600 with each gun gives us a pretty good idea of just how the bullets fly out of over 200 guns. The question of when a bullet goes to sleep depends on the rpm. And the rpm runs from 180,000 and up depending on the twist the slower the twist the sooner it goes to sleep until you get so slow that it doesn't stabilize at all. A 300 Win Mag will shoot a bullet out of a 1 in 12 twist barrel 3000 fps = 3000RPS or 180,000 rpm. During the accuracy tests of the M88, the guns consistently shot 1 1/2 inches at 100 yds, that's 1.5 MOA. The same guns, many of them shot 2.5 inches at 600 [Author's Note: 0.25 MOA] and very few shot as bad as 6 inches. Why do you suppose that we were required to test them at 600?

This is a phenomenon that has been known to the benchrest shooters for a long time because they were shooting rifles at 100 and 200 yards that were accurate enough to see it. Not many rifles and shooters will shoot well enough to recognize the difference. It is occurring at a much faster interval now that everyone is shooting long bullets out of super fast twist barrels. I will go back to the top you had as a kid. When you threw it hard it would hunt in a circle and as it slowed down it would go into a wobble and as it slowed more it would go to



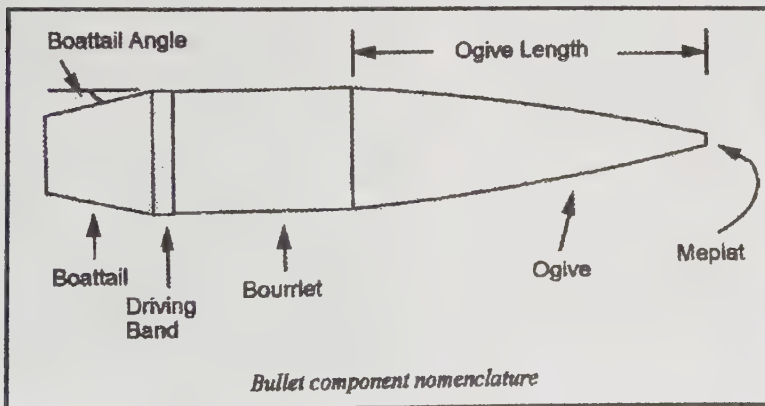
Four machined bullets (1, 3, 4, and 5) compared to a standard flatbase bullet.

sleep and stand in one place until it became unstable and started to wobble again and fell over. That is exactly what a bullet that is turning faster than is necessary to stabilize it will do. If it were possible to have the bullet leave the barrel at exactly the same speed then they would go through the same hole but since there is a variation in velocity they strike the paper at different points of the spiral you have holes around the spiral. This will probably go on forever as it seems hard for some people to grasp.²¹

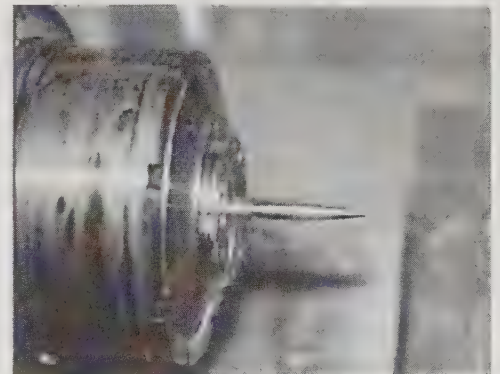
Buddy Clifton: The top, as Gale used as an example, is a good example but there is another dynamic difference with bullets. The top's action is linear with one fixed point. A bullet does not have a fixed point like the top. There is not only linear, but nonlinear action with projectiles. Accuracy of the bullet is fully dependent on these two factors. Linear, out to 100/200 yards, takes in the angle of departure from the center line of the bore. This is also called the initial line of departure. Nonlinear, which is almost zero close up, take in drag, wind effect, and muzzle velocity. The ratio of a bullet is about 1/3 linear to 2/3 nonlinear. As you can see nonlinear action will affect the bullet's accuracy the most. The VLD designed bullets, because of the longer length and boattail are more nonlinear than a flat based projectile. It just so happens the VLD has a smaller drag coefficient.

Accuracy, say, out to 1,000 yards, boils down to how much recoil can you take. For example, if a naval 16-inch gun could be shot off the bench, impact at 1,000 yards, the nonlinear effect would be extremely low. However, recoil, to put it mildly, could not be tolerated. To calculate the effects of linear and nonlinear influences for accuracy, a relatively quick way is to divide the distance by the caliber in inches and look at the product. The 16-inch product at 1,000 yards is 62.5 with .50 being 2000. Sometimes I wonder why wind flags are placed at the target. Hurricane force winds could be present at the target and it would not matter because the bullet is already at where it wants to be. Calculating the best velocity for a certain bullet cannot be done because there is no such thing as the optimum speed at the target. You know, I never did find out what range to use to make sure I was getting typical group sizes for working up loads with the .50 BMG!²²

While the different RPM and also the bullet's quality in construction will have a factor in determining a bullet's need to go to sleep, there are a couple of ways to ensure a bullet has the high quality needed for competition and extreme range anti-personnel use. One of these factors is in the reloading process. The quality of the case, its preparation, the powder charge, the selection of the



Bullet component nomenclature.



Ready to cut off a 750 gr. VLD.



primer are all part of the loading methodology. The other factor is the bullet construction itself. Without a doubt the most accurate bullets are CNC lathe turned bullets.

These photos of the machining process (on previous page) were taken in Lynn McMurdo's shop in Wyoming. His bullets are considered some of the best in the competition and should be considered by extreme range anti-personnel operators. Remember, all targets don't need explosive projectiles, only high precision bullets to ensure a strike at the extreme ranges.

The machining process is a very specialized procedure that requires not only special skills in machining, but in bullet design as well. You can be sure that the makers of these special bullets have spent hours and days on the range perfecting their design. To their credit, they do an outstanding job and readily share their bullet craft. The material that goes into the bullet is also critical. Many different steels and alloys have been tried and used. This next article is an article solely on the materials used for the construction of turned monolithic bullets for the .50-caliber.

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MATERIALS FOR .50 CALIBER BULLETS

by Daniel Lilja, VHP 1996 #2

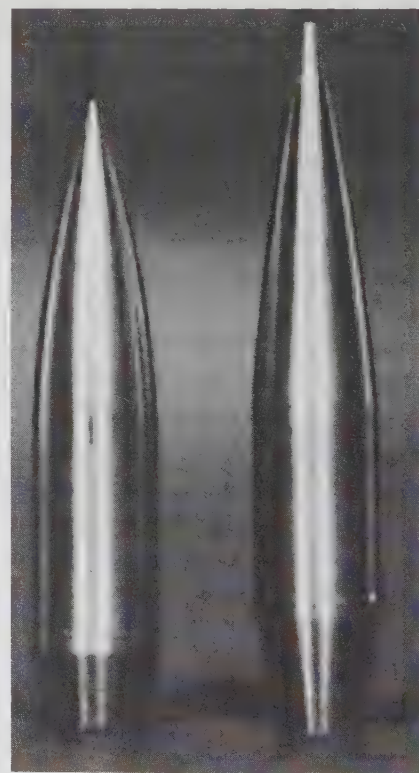
This article was prompted by a desire to look into the differences in materials used in making solid, monolithic construction, fifty caliber bullets. Most of the bullets made commercially and by experimenters have been made from one of several materials. The list includes brass, bronze, copper, and steel. Generally these bullets are made on CNC-type lathes or screw machines, and in the case of the steel bullets, Zero Index follows the turning operation with a centerless form grinding step. Another exception are the bullets made by Accurate Projectile Technology. These are made from cold forming copper bar stock. I'm not sure how the Thunderbird bullets are made, but I think they're cast from melted down cartridge brass and then tumbled.

I'll attempt to share what I've learned from shooting some of these bullets and from research I've done on the materials. I wanted to know what weight differences could be expected for bullets made from these various materials. And how did this weight difference affect internal and external ballistics? What, if any, effects on accuracy did each material offer?

Effects of Density on External Ballistics

These four different materials each have their own density. Their effect on the ballistics of bullets made from them is twofold. The gyroscopic stability of a bullet increases along with density, meaning that it takes less barrel twist, or bullet spin, to stabilize a bullet. From an accuracy point of view, that's a desirable characteristic. Slower twists are more accurate, especially with poorer quality bullets. The second effect of bullet density lies with ballistic coefficient.

Since high ballistic coefficients are desirable, we can see that if we increase the sectional density of the bullet, BC will rise.



Zero index monolithic bullets.

Alternatively, the form factor could be reduced. Form factor is dependent on bullet shape and this subject was covered very well by Eric Williams in *Very High Power* 1993, issue #3.

It's obvious that if one material is denser than another, a bullet made from the denser of the two will cause a bullet made from that material to weigh more. This increase in weight will therefore increase the bullet's ballistic coefficient. The term specific gravity is a measurement of a particular material's density. A value is assigned to all materials indicating specific gravity. For example, lead has a specific gravity of 11.34. Water has a specific gravity of 1.0 at 62 degrees F., and is used as the yard stick in measuring specific gravity for all other materials. This means that for a given volume, lead will weigh 11.34 times as much as the same volume of water.

A jacketed lead-core, soft-point bullet has a specific gravity from 10.25-10.4, depending on the ratio of lead to copper. A jacketed hollow point will measure from about 10-10.11. Now let's turn our attention to monolithic solids. The specific gravities of these materials follow: copper 8.89, bronze, 8.78, brass 8.2- 8.6 (depending on the alloy), and steel 7.64-7.85 (depending on alloy again). So by a small margin, copper is denser than bronze, followed by brass and then steel. Until I looked up these values, I thought that steel was quite a bit lower than the other materials. Of academic interest only, silver has a specific gravity of 10.5 and gold 19.3.

I wondered then, what would various bullets weigh, all the same size and shape, but each made from a different material from the list above? And what would each bullet's ballistic coefficient be? To answer the weight question, I used a computer program I wrote in GWBASIC that calculates a bullet's weight from its physical dimensions and specific gravity. An article describing this process and a listing of the computer code was printed in *Very High Power* in the 1992, #2 issue.

Remember, the shape of these bullets stayed the same, therefore the form factor did too. For bullet shape, I chose one that is similar to the 700 grain, steel bore-rider offered by Zero Index. Actually this bullet weighs about 703 grains on my scale. Not coincidentally, the shape of the Mance 765 grain brass bullet is almost the same. There is a little difference in the driving band, but not much. The physical dimensions I plugged into the weight program are: a bullet diameter of .502" (driving band of .511"), 2.500" overall length, 8 caliber tangent ogive, a meplat diameter of .005", and a boattail .240" long with an end diameter of .410".

I found that a copper bullet would weigh 809 grains, a bronze bullet 799 grains, one from brass 765 grains (like the Mance) and the steel version 703 grains (like the Zero Index). If we had more dollars than sense, a gold bullet would weigh 1757 grains.

Answering the ballistic coefficient question is a little more involved. I used a program written by Bill Davis of Tioga engineering and Bob McCoy of Aberdeen Proving Grounds. This program calculates both C_I and C₇ form factors and ballistic coefficients. It does so from specific inputs about the geometry of the bullet and its velocity. Throwing velocity into the calculations complicates our question here, because as we know, lighter weight bullets can be driven to higher velocities. Ballistic coefficients normally increase with velocity.

Effects of Weight on Internal Ballistics

So, before we can answer the ballistic coefficient questions, we must first make some accurate assumptions about what velocities we can push from our four different density bullets. In another article I wrote for the *VHP* about velocities and barrel lengths, I mentioned an internal ballistics program that I used for predicting velocities. This program has been an accurate predictor of velocities, so I relied on it to help me out again. In the earlier article I just changed barrel length, looking for velocity differences. This time I left

barrel length the same, 36", and changed bullet weights. (I won't go into details again about how the program works: those who are interested or skeptical can look up that article.)

The internal ballistics program calculated that if we started the 809 grain copper bullet at 2686 fps, then the 799 grain bronze bullet would leave the muzzle 14 fps faster, at 2700 fps. To my surprise, it said the 765 grain brass version would be pushed to an even 50 fps more, or 2750 fps and the 703 grain steel bullet would be an even 100 fps quicker, at 2850 fps. It's unusual for velocities to be spaced at nice 50 or 100 fps intervals, but that's what the computer said. These velocities are reasonable from a 36" long barrel with a 50 BMG chamber.

Calculating C I Ballistic Coefficient

Now that I knew both bullet weight and comparable velocities, I could put those numbers into the ballistic coefficient program. Of passing interest, I also put those numbers through another Tioga Engineering program that accurately calculates gyroscopic stability. This program determines which twist rate will yield a stability factor of 1.5 by using physical dimensions and specific gravity data, along with velocity. Without going into a lot of discussion about the stability factors, a value of 1.5 is looked on as a conservative number, giving both accuracy and adequate stability for any normal conditions. If the stability factor drops below 1.0 this indicates that the bullet is not stable in that particular twist rate. By bringing this number into the discussion we can see how stability decreases along with specific gravity.

I found that the copper bullet had a C I ballistic coefficient of .992 and a 15.1 twist rate gave a stability factor of 1.5. The bronze bullets ballistic coefficient was close, at .981 and a twist rate of 15.1". The yellow brass bullet needed a 14.7" twist and the C I value was .944. The magnetic bullet liked a 14.2 twist rate, and had a B/C of .879. Zero Index states that the ballistic coefficient of this bullet is about .89, so our number looks pretty close. These ballistic coefficient values are said to be accurate to within about 5 percent. They should show closer accuracy between each other however, because the form factor is constant. Looking at it another way, if one is off by 5 percent, they're probably all off the same amount, making our comparison valid.

Putting It All Together

The big question should be, how does all of this theory affect a bullet shot at a target 1600 yards away? Ballistic coefficient and velocity affects bullets in two important ways, as far as the paper puncher is concerned. Those two things are bullet drop and . . . even more important in my opinion . . . wind drift.

Again, we can accurately calculate drop and drift at 1,000 yards if we know bullet ballistic coefficient and velocity. And again, I relied on another Tioga Engineering program (TRAGIQ) to do so. The computer indicated that the copper bullet would drift about 39.39" at 1,000 yards in an 10 MPH direct cross wind, and that the total bullet drop would be 308.1". The bronze bullet would blow 39.62" and drop 305.7". As we would suppose, the performance of these two bullets is almost identical. From a practical point of view, they are ballistic twins. The brass bullet shows a drift figure of 40.41" and total drop of 297.4". To me, the interesting one is the steel bullet, drifting 41.84" and dropping the least, at 281.8". All of these numbers are based on a standard sea-level atmosphere. Increasing elevation or temperature will decrease both values.

Musing on Materials

I've also made some observations about the materials we have mentioned, not related to ballistics. One concern with all of the solids is barrel wear. In my opinion, the jury is still out

on this subject. I'll leave the discussions about various barrel treatments, bullet coatings and virtues of chrome-moly versus stainless steel barrels to others.

In my experience, copper bullets tend to be metal foulers in the barrel. However, with appropriate cleaners and periodic use, the shooter can normally stay on top of fouling. Material cost is higher than brass, but not out of sight. As we saw, copper also has the highest specific gravity and resultant sectional density. Copper can be challenging to machine, but APT's cold-forming operation eliminates this problem.

Bronze is the most expensive material of those we mentioned (not including gold, of course.) It's also the most slippery, having the best friction coefficient. I've fired some bore rider bronze bullets in a stainless steel barrel with virtually no fouling. The specific gravity for bronze is close to that of copper.

Brass is the least expensive of the non-metallic metal. In my experience, it also tends to foul about like copper does. Fortunately the same cleaners that remove copper will also take out brass. The specific gravity is lower than both copper and bronze, but not by a great deal.

Steel is the most interesting material for bullets in my opinion. Its biggest advantage, as I see it, lies in the fact that it does not foul. And if it does start to foul, it may be a "self healing" type fouling. Steel bullets are the hardest on barrels, and experienced shooters suggest they be fired only in chrome-moly barrels. I would agree with this recommendation too. The leadloy-type steel (12L14) used in these bullets is very machinable. It also holds tight tolerances well, probably better than the other materials. Steel is quite a bit cheaper than our other bullet materials. But long term storage may be a concern due to potential rusting. Steel has the lowest specific gravity, which could be looked on as a mixed blessing.

I found that there wasn't really much practical difference in the ballistics of the copper, bronze, and brass bullets. Because the weight of each decreased in the order just listed, they could be driven faster as they got lighter. This characteristic made up for some of the decrease in ballistic coefficient as related to wind drift. There was only about 1" more drift at 1,000 yards for the brass bullet compared to the higher BC copper bullet. The brass bullet actually dropped about 10.7 inches less. Drop is not important though, if we're zeroing the scope at 1,000 yards. From a barrel fouling point of view, bronze is probably the best. It's the most expensive too.

The bullet that shined in my eyes was the steel one. Because of its decreased weight, it can be pushed more that 150 FPS faster than the copper bullet. This big velocity advantage almost makes up for the decrease in ballistic coefficient, the steel blowing just 2.4" more at 1,000 yards. The steel dropped 26.3" less than the copper. That's a fairly significant impact change of over 2 feet. It's no secret either, that in the hands of good shooters using top equipment, the steel bullets have won a big share of recent matches. Perhaps, as the saying goes, all that glitters is not gold??

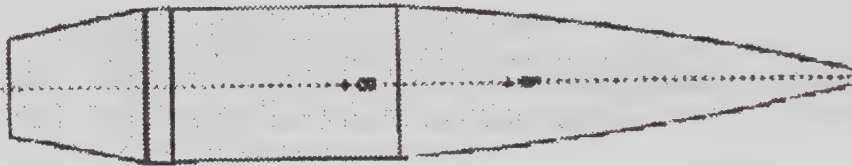
Notes about the chart: For the 4 material types shown, the bullet shape stayed the same. It was a driving band-type bullet with a .502" diameter body, 2.5" overall length, 8 caliber tangent ogive, a .005" diameter meplat, and a boattail .240" long with an end diameter of .410".

COMPARISON OF COPPER, BRONZE, BRASS, & STEEL 50 CALIBER BULLETS							
MATERIAL	SPECIFIC GRAVITY	VEL. FPS.	C1 B/C	TWIST RATE	WIND DRIFT	1000 YD. DROP	WEIGHT
COPPER	8.89	2686	.992	15.11,	39.39"	308.1"	809 GR.
BRONZE	8.78	2700	.981	15.0"	39.62"	305.7"	799 GR.
BRASS	8.4	2750	.944	14.7"	40.41	297.4"	765 GR.
STEEL	7.72	2850	.879	14.2	41.83	281.8	730 GR.

COMPARISON OF COPPER TO STEEL 50 CALIBER BULLETS

	<u>COPPER</u>	<u>STEEL</u>
WEIGHT	809 GR.	703 GR. (-13%)
VELOCITY	2686 FPS	2850 FPS (+6.1%)
C1 B.C.	.992	.879 (-11.4%)
10 MPH WIND-1000 YARDS	39.39"	41.83" (+6.2%)

Therefore, the weight for each bullet changed because of differing material densities. Relative density is represented by the term specific gravity. The estimated velocity was calculated by an accurate internal ballistics program. The C1 ballistic coefficient was also computer-calculated from shape, specific gravity and velocity inputs. The same is true of the calculated barrel twist rate, resulting in a stability factor of 1.5 in each case. Wind drift (10 MPH) and drop figures, at 1,000 yards, were computed by an external ballistics program and based on ballistic coefficient and velocity. All external ballistic coefficient and twist rate data is based on a standard sea-level atmosphere. Increasing the temperature or altitude of the gun will decrease drift, drop, and required twist.



General Stability Output from PRODAS Program using the new Zero Index Bullet as an Example

Projectile Length = 2.7000"

Ogive Length = 1.5000"

Boat Tail Length = .45000"

Driving Band Length = .5400"

Muzzle Velocity = 2700 fps

Spin Rate = 2160 (CPS) 2.296 calibers

Air Density = .002377 slug/ft³

Center of Pressure from Nose = 1.1525" 3.376 calibers

Gyroscopic Stability Factor = 1.221

BALLISTIC CO-EFFICIENT (C1) = .987

This chart (top) compares the differences between the two bullets with the greatest weight differences, made from copper and steel. It is interesting that the weight decreased by 13/1 percent with steel, but the ballistic coefficient decreased by 11.45 even though the form factor remained the same. This is due to the fact that ballistic coefficient increases with velocity. Since the steel bullet is lighter, it can be driven to higher velocities. The wind drift for steel is 6.2 percent greater, but drop is 8.55 less at 1,000 yards.²³

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As we go through the section on heavy bullets, we have looked some of the metals used in monolithic solid bullets. These clearly, are not the only ones that are available. This next article by Eric Williams compares various bullet designs that are of jacketed, solids, and bore-riding design.

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COMPARING VARIOUS BULLET DESIGNS

by Eric Williams

Two issues ago the fundamentals of bullet design were discussed on a technical level. To follow up on this topic, I want to present some practical aspects of bullet design as they relate to fifty caliber bullets. With an understanding of the fundamentals, the pro and con arguments comparing the various bullet designs currently available will be more easily understood and accepted.

I've divided the various types of fifty caliber bullets into four classes based upon their construction, and I will discuss the merits and drawbacks of each type of design separately. Armed with this information a shooter will more easily be able to select a bullet for their particular application.

The four classes of bullets are the traditional lead core designs, solid alloy designs, bore riding / driving band designs, and military designs. This division of designs is not arbitrary. Each class has an arena where it shines and another where it performs poorly. Quite often a shooter will design their rifle around a particular bullet design they wish to use. This may sound backwards but considering the importance of the bullet to the overall performance of a shooting system, it is often a wise protocol.

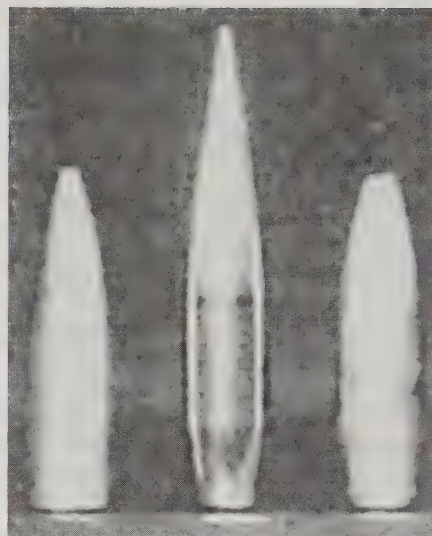
A number of attributes which will be discussed are accuracy potential and the factors effecting it, fouling characteristics, wear on barrels, terminal performance, adaptability to various gun designs, ballistic performance, price and availability. I must admit that the true test of any bullet is in the field. The sport of shooting involves many variables; many which are close to impossible to quantify. With this in mind, I'll try to maintain a division between hypothesis and what has been proven by experiment. In many garages, basements, and labs the scientific method (problem, hypothesis, experiment, conclusion, hypothesis, experiment . . . fact!) is ongoing and, therefore, all the facts on these various designs are not currently available.

Traditional Lead Core Designs

Being the best known design to the small arms shooter, I will not insult your intelligence by describing the construction of this bullet in detail. Typically, this is a two piece bullet with a lead core and a copper jacket. The new Hornady bullet is a three piece bullet with the addition of an aluminum insert to the lead core and copper jacket.

The lead core bullet's greatest assets are their adaptability to a variety of rifles and tasks. Bore and groove diameters can vary as a result of wear or manufacturing tolerances. Because of the lead core, this design results in a very pliable bullet. Pliability is important since this type of bullet can either swage or obturate to fit either an undersized or oversized bore. The bullet to bore fit is extremely important to good precision and accuracy.

Lead cored bullets can be designed to provide the proper terminal performance required for hunting. In fact they are the only design which I can recommend for big-game hunting. In particular, Lynn McMurdo's bullets have numerous big-game success stories to their credit. I cannot, at this time, recommend the Hornady bullet for big-game hunting. It was designed for match shooting without any thought towards terminal performance on soft tissue. I'd like to see some tests done on wet newspaper



Some lead core designs (left to right): A McMurdo flatbase, the new Hornady, and an RIS.

or ballistic gelatin with the Hornady bullet in order to see if it has any potential for hunting.

The lead core design also offers the bulletmaker the ability to move the bullets center of gravity without changing the overall form by varying the configuration and size of the lead core. This ability is demonstrated by the new Hornady design.

This bullet sports an aluminum nose insert which puts the center of gravity farther rearward than in a solid design of the same weight. Moving the center of gravity rearward reduces the bullet's dispersion

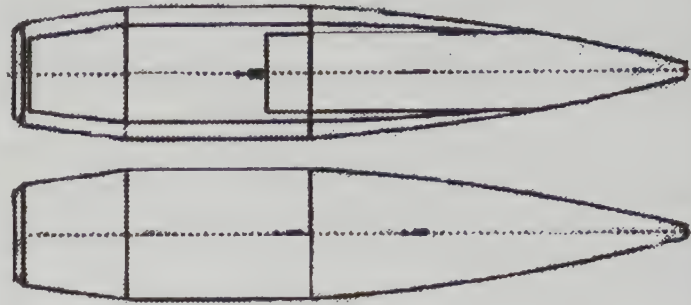
sensitivity. In fact the Hornady bullet possesses 40 percent lower dispersion sensitivity than a solid bullet of the exact external shape. Hollowpoint bullets also have a dispersion sensitivity advantage over solid designs for the same reason. The dispersion sensitivity is important to accuracy since it determines the amount of dispersion due to bullet misalignment, runout, and other imperfections.

I do not know of any test data that shows the relative bore wear of fifty caliber lead core bullets to the other designs, but I feel quite certain they are easier on bores than the other designs. I know of cases where barrels have been worn out in less than 1,000 rounds with solid designs, but I've never heard of a barrel wearing out this fast with lead core bullets. I have also not heard of any major fouling problems resulting from lead cored bullets.

On the downside, lead core bullets are more difficult to consistently produce than solid bullets. Jacket inconsistencies, core seating and core bonding problems are items which the maker of solid bullets doesn't have to be concerned with, and problems such as these have a significant impact on accuracy.

With the exception of the new Hornady bullet, all the lead cored bullets that I'm aware of possess lower ballistic coefficients than equal weight solid bullets. Hornady solved this BC/weight tradeoff by using a substantial amount of aluminum in their bullet. Regarding wind deflection and maximum accuracy range; ballistic coefficient is paramount.

The going price for custom lead core bullets is \$2.00 each. For a low volume product involving a lot of hand work, this price is very fair but may still be too steep for those on a restricted budget. The Hornady bullet, due to Hornady's mass production capability, is priced around half that of the custom bullets, which makes its price competitive with the cheapest fifty caliber bullets.



These PRODAS drawings show the relative positions of the center of gravity between the Hornady design and a solid design of the same shape. The aluminum insert results in a significant shift of the center of gravity.

Solid Alloy Designs

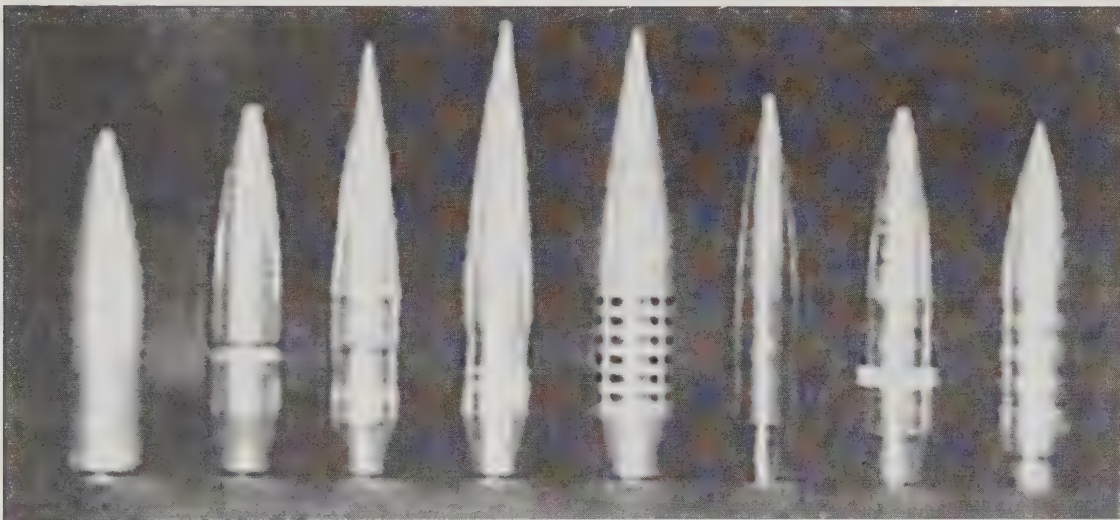
This solid alloy bullet is the most commonly found design among fifty caliber bullet makers today. These bullets include those made by TCCL Barnes, Hollywood Engineering, G. McMillan Gunworks, and other custom manufacturers. Most of these bullets are cut from solid bar stock by a screw machine or lathe device. As long as care is taken to avoid runout and dimensional variation in the turning process, this design of bullet is the most consistent. This consistency is demonstrated by the domination of this bullet design at matches. In particular, the TCCI bullet has proven its quality over the years in matches. In the hands of Dennis Chapman and Jack Hollinger, the Barnes 800 grain bullet also has a number of match wins to its credit.

Considering the optimal density of copper alloys for the fifty caliber bore, these bullets

possess a good BC/weight combination. As mentioned earlier, Hornady obtained a good BC/weight combination with their new lead core design but at the cost of adding a third component. The negative aspect to the Hornady design as compared to a solid design is that it's much easier to make a low dimensional tolerance one-piece bullet than a three-piece bullet.

Solid alloy designs are much less forgiving when it comes to variations in barrel dimensions. One needs to closely match their bore's groove diameter to the diameter of the bullet they wish to shoot. It's best when the groove is .0001 to .0005" smaller than the bullet diameter; any smaller and pressures, wear, and fouling increase, while with a larger groove gas leakage occurs along with a significant loss of accuracy. The need to match diameters comes from the inability of the solid alloy bullet to swage or obturate to the degree a lead core bullet can. This need for a precise fit will cause the most discerning shooters to sort bullets by diameter and runout, since most of these bullets are not manufactured without minor variations.

As a result of the necessary interference fit between the bore and the bullet along with the poor swaging ability of the solid alloy bullet these bullets tend to foul heavily. Upon engraving the extra bullet material has nowhere else to go than to deposit on the barrel. I've found that most of the bullet fouling is deposited near the throat of the barrel, which is consistent with this explanation. I've used an Outers Foul-Out cleaning unit to keep ahead of the fouling problem with success.



Solid designs (left to right): TCCI 700 gr, TCCI 750 gr, Barnes 750 gr, Barnes 800 gr, experimental design 810 gr, McMillan 780 gr, Hollywood 770 gr, Horstkamp 764 gr. A large variety to say the least!

One of the most talked about problems concerning the solid alloy bullets is barrel wear. I'm not sure what, in all the talk, has been proven about wear, but I do believe that barrel life with solid alloy bullets is shorter than one is commonly accustomed to with smaller guns. Whether it be because of rapid barrel wear or the bullet's sensitivity to a small amount of barrel wear, barrels when fed a steady diet of solid bullets usually do not last more than 1,000 rounds before their match grade accuracy with solid bullets falls off. In order to mitigate this problem, I strongly recommend using chrome-moly steel barrels with solid alloy bullets. Although stainless steel resists throat powder erosion better, it does not hold up as well to the wear that solid bullets present.

Barnes has designed their bullet with a much smaller amount of engraving surface to cut down on barrel wear. To date, I'd have to say that the verdict is still out as to whether or not this design feature accomplishes its goal. With the variety of barrel steels, rifling methods, and the fact that most barrels are exposed to more than just one bullet make, barrel wear data is always difficult to find and is always suspect.

My feelings along with data from matches bear out the fact that one must consider this design of bullet if they are looking for a high level of long-range accuracy, and once this accuracy is found one usually finds a way to put up with the fouling and wear problems.

As I mentioned earlier, do not use this design of bullet for big game hunting. In most states the use of solid and full metal jacket bullets for big game hunting is illegal, anyway. A high BC spitzer does not open up as large of a wound channel as a solid round nose bullet will. Unless a vital organ is hit or secondary bone fragments connect with a vital organ, chances of a wounded animal are high. I had a groundhog run away after being hit with a solid TCCI bullet, since only a stomach hit was made. When it comes to hunting, bullet design and placement are so important that arguments between which caliber and cartridge is better are minor in importance.

One will find most of the solid alloy bullets competitively priced around \$1.00 each. When you consider the cost of the raw alloy and the machine time, they are fairly priced. I've looked into having some special designs of my own made and have come to the conclusion that if price were an issue it would be best to buy what already exists.

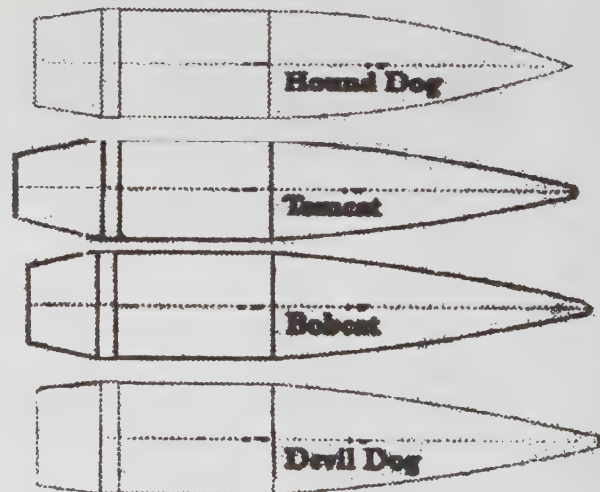
Bore Riding Designs

Although the bore riding projectile design has been the rule with cannon projectiles, they were first introduced to the fifty caliber shooting game by Bill Bieber. Currently, they are being made by Zero Index using a centerless grinding process which produces near zero dimensional tolerances.

For the most part this design of bullet has been produced from 12L14 Ledloy steel. Newer designs from both Barnes and Zero Index will soon be available in copper alloys; although, the use of copper alloys results in the need to increase the length of the driving band. Copper does not wear near as well as steel as a driving band material. Driving bands from copper need to be about 0.20" long while those from steel work when only 0.085" long.

This design came about from a need to reduce the perceived fouling and wear associated with other solid bullets. By making the bullet from steel, copper fouling no longer existed. Although steel bullets can be a disaster when it comes to barrel wear, the problem was mitigated when only 0.085" of the bullets bearing surface was engraved.

Everything said about the dimensional match required between the bullet and barrel with solid bullets holds true with the bore riding design as well. They are also not recommended for big game hunting. An additional requirement for



Depictions of the various bore-riding designs manufactured by Zero Index (not exactly to scale). Barnes is also producing a Hound Dog type design in copper alloy.

optimal performance with these bullets is the need for specially cut throats without any freebore. Skip Talbot described the throat he has used to set records with in an earlier issue. An article will be forthcoming describing this technology in detail.

When you buy these bullets from Zero Index you are getting the most consistently made bullet money can buy. There is no need to sort these bullet; no culls can be found. I think this consistency has demonstrated itself by the fact that Zero Index bullets hold both the FCSA single target and aggregate target records.

Several designs of this type bullet currently exist. The original Bieber design has been named the "Hound Dog" by Zero Index. Also, Zero Index makes the "Tomcat" (the original PRODAS design), the "Bobcat" (a shortened Tomcat), and the "Devil Dog" (to be produced in both steel and copper alloy). The original Hound Dog has been around the longest and has the records to its credit. It does have a relatively low BC (0.68) and attempts to improve on the BC have resulted in the other designs. We have not been as satisfied with the Tomcat design as we had hoped. It seems that the gyro and dynamic stability were very marginal because only guns with new barrels would shoot the Tomcats. This bad news resulted in the development of both the Bobcats and the Devil Dogs. Time will tell if these designs have the right combination on accuracy and Ballistic Coefficient.

I must warn shooters that there is a price to pay for the quality of these bullets. Zero Index sells the Ledloy designs for \$1.50 each and the bronze ones for \$2.35 each. The bronze designs carry a premium because of the expensive non-galling bronze alloy which is used. It may not count for much, since I haven't been winning matches lately, but these are the bullets my gun will be shooting this coming match season.

Military Designs

Practically all military bullets for the fifty caliber are multiple piece designs which were not designed with precision in mind. They make great plinking bullets. Especially the pyrotechnic designs, but they will not compete in matches. With the exception of pure tracers, all have steel cores. The lack of good bonding of the steel core with the jacket contributes to the poor accuracy of these bullets.

These bullets are made from three to seven components, which makes them difficult to build consistently. For reloaders the IMI ball bullets are the only ones readily available, either from Speer or IMI resellers. Fortunately, for military ball projectiles, the IMIs are some of the most consistent and can be expected to hold at or under two MOA groupings.

The military design bullets do not seem to present any exceptional wear or fouling problems. What they lack on precision is made up for with terminal performance on hard objects (speaking of AP, API, APIT, and BE designs). I cannot recommend these bullets for hunting applications but they are great for junk yard shoots against old cars.

Regarding price for loaded ammo, it runs the gamut. I've bought Dominican surplus



Selection of military bullets: M33 Ball, IMI ball, 12.7 Russian API, M8 API, M17 Tracer.

ammo for 60 cents each and I've heard of people paying \$35.00 each for shooting quantities of HE ammo. Prices around \$2.00 each for new ball ammo is fair, while the pyrotechnic stuff, where legal, will run generally from \$2.00 to \$4.00 each.

When trying to choose a fifty caliber bullet one must first consider the application intended for the bullet. For strictly plinking, one will probably consider price and availability first. Most likely you'll end up with some military surplus ammo, when available, for plinking games. For high accuracy, long-range applications, look first to the new Hornady design or the other proven solid designs. Here one has a reasonable breadth of choice, and the only solution is to try a number of designs.

One final point: if you are shooting where ricochets could be a problem, avoid the solid and military bullets. They are notorious for ricochets. You'll need a lead cored, frangible bullet for these applications. As always, safety first!

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PART III: THE BULLETS

While we have looked at many different cartridges, bullets, types of bullets and their construction, we have not yet looked at what goes into designing a bullet. As you later see in this chapter, there are many different custom bullet makers in the country, much more than most people realize. They make some very fine hardware and have contributed a great deal to the advancement of extreme range shooting. The craft of making a bullet is not that difficult. The officer in charge of the sniper committee at 1st SFGA, Fort Lewis made his own .30 caliber match bullets for use in competition.²³ The ones that I used were 185 and 195 gr. rebated boat-tails with a hollow point. Out of my tactical .300 magnum, I scored over 195 on three occasions with a high of 198. The were the best bullets that I had shot, including Sierra Matchkings and the Lapua D-46 bullet.

The next section is an article by Eric Williams on bullet design. It is also about a design program called PRODAS. The article is long on some very technical stuff but with some careful following in reading, some very neat stuff sticks its nose out. The article also will go into a theoretical bullet design.

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THE FUNDAMENTALS OF BULLET DESIGN: A NEW BULLET DESIGNED BY PRODAS *by Eric Williams*

Just as a barrel is to a gun, a bullet is the key component to a cartridge when one is concerned about precision performance. There are key design elements which constitute a complete bullet. These design elements include: overall length, driving band length, boattail length, ogive length, ogive radius, boattail angle, meplat diameter, material of construction, and jacket thickness (if a jacket is used). Whether one's approach to bullet design is to make a few changes to an already existing design or to design a bullet from scratch, it's important to understand the effect each one of the design elements has on the overall performance of the bullet. This is especially important when one considers there are an unlimited number of combinations of the various design elements and most of those possible combinations will simply not work. If you are a bullet designer or wish to be one, how do you know which of the unlimited design possibilities will work and which of the possibilities will be the best for your particular application? This question cannot be adequately covered in just one article. What I can leave with you are a few generalities of just how modifications on the bullet design elements affect performance and what tools are available to aid in your design.

Free flight dynamics and bullet design are complex subjects. The physics of these subjects has been known for some time but it is only recently that computer models have been developed which can be used routinely. In 1972, under contract to Picatinny Arsenal, General Electric began development of a general projectile design and analysis tool; that tool is called PRODAS which is an acronym for Projectile Design/Analysis System. PRODAS is a trademark of the General Electric Company currently used under license by Arrow Tech Associates. PRODAS can compute a projectile's inertial properties (weight, center-of-gravity location, axial and transverse moments of inertia), estimate aerodynamic coefficients (three force and three moment coefficients), compute gyroscopic and dynamic stability factors, estimate dispersion, and simulate trajectories. In the seventies and early eighties only mainframe computers could handle the computational tasks of PRODAS. Since that time, PC's have arrived which provide as much power as earlier mainframes. Arrow Tech Associates has developed a personal computer version called PC-PRODAS which brings the power of state-of-the-art bullet design to everyone. Arrow Tech Associates has given me a full working trial copy of PC-PRODAS which has taught me some important elements of bullet design and has allowed me to design a new .50-caliber projectile.

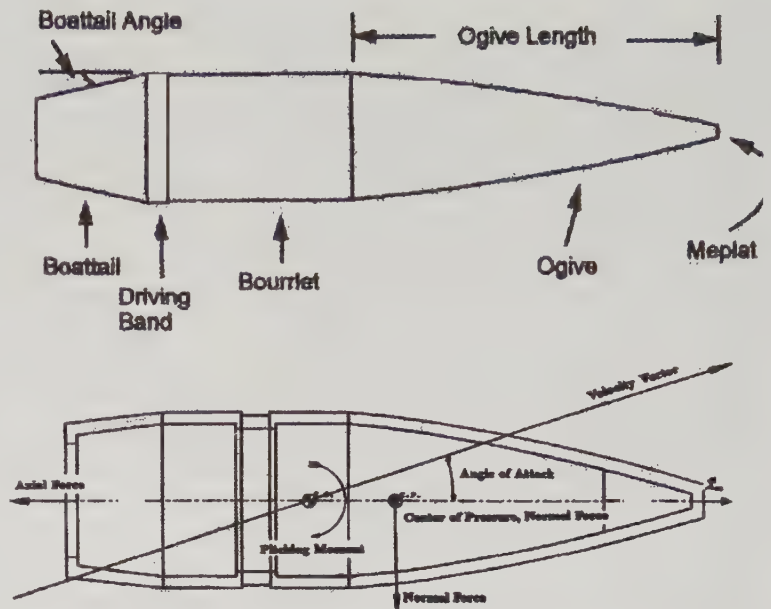


Diagram identifies the primary forces and moment acting on a spin stabilized projectile in flight. The Magnus, pitch damping, and spin deceleration moments have been omitted for clarity.

The Primary Considerations of a Bullet Designer

There are five items which must be taken under consideration when designing projectiles. First, gyroscopic and dynamic stability must be considered. Without sufficient gyroscopic (to ensure the bullet doesn't tumble) and dynamic stability (to ensure that the yaw decreases downrange) the bullet will not fly nose first, period. A consideration of high importance to the long-range shooter is the ballistic coefficient. With ballistic coefficient it's not a question of if the bullet will work, but just how well it will work. Another consideration, which is probably the most neglected by bullet designers, is the bullet's dispersion sensitivity. Depending on the particular design, a particular amount of minimum dispersion can be expected resulting from bullet yaw. One would obviously want to minimize dispersion. The fourth consideration is the material and method of construction. By method of construction, we are talking about jacketed bullets versus homogeneous solids. Depending on your requirements there are advantages to each of these designs, and each design and their material of construction has implications on the bullets performance. Finally, terminal performance is usually an important consideration. Since this treatise will deal with paper punching bullets, I won't address this topic, but whether it's bullet performance on game or on armor, terminal performance is usually a very important consideration.

Gyroscopic and Dynamic Stability

We'll start with gyroscopic stability since this is probably the essential consideration in bullet design. A bullet can have two types of rotational motion. One is generally referred to as spinning and the other is tumbling. Momentum associated with spinning a projectile is referred to as the axial angular momentum. It is the axial angular momentum which opposes the normal (perpendicular) forces which try to tumble the bullet. Since these quantities can be derived by a combination of computational and empirical methods, one can calculate if a bullet will be stable and by how much. There is a simple tool available called the Greenhills formula for calculating the required twist for stabilizing a particular bullet. This formula, frequently, will give a correct answer, but it doesn't work for all bullet designs and it doesn't give any indications of the degree of stability. The Greenhills formula only considers a bullet's length relative to its caliber. PRODAS considers all factors that affect spin stability. The result is the gyro stability factor (Sg) which must be greater than 1.0 for a bullet to be stable. The formula used by PRODAS to calculate the gyro stability factor is shown below.

The numerator of the equation represents the axial angular momentum of a spinning bullet. It depends on the spin rate squared and the axial moment of inertia squared. The axial moment of inertia of a bullet is proportional to the diameter of the bullet squared times its mass. To be exact, the axial moment of inertia depends on the relative placement of mass to the rotational axis. For instance, a copper jacketed lead-cored bullet will have a lower moment of inertia than a hypothetical lead jacketed copper-cored bullet of the same dimensions and mass. Since the mass of a bullet is dependent on its density, one can see higher density materials of construction will lead to bullets with higher moments of inertia. The rotational rate is also found in the numerator as one would expect; higher spin rates translate into higher stability factors.

The denominator of the equation contains factors that deal with the forces involved with tumbling the bullet. Since tumbling is a rotational movement the transverse moment of inertia becomes an important factor. As with the axial moment of inertia, the transverse moment of inertia depends on the placement of mass relative to the axis of tumbling which passes through the center of gravity of the bullet. The transverse moment of inertia is proportional to the square of the length of the bullet. As we already know from the Greenhills formula, stability is strongly dependent on the length. Generally, bullets should be kept under six calibers in length or else gyro stability will be difficult to achieve.

Some shooters have found out the hard way about the dependency of stability on air density. Bullets marginally stable during summer matches probably won't fly during the winter because of an increase in the air density. As indicated by the above equation, if we were to double the air density we would halve the gyro stability factor.

The pitching moment coefficient is a bit more complex of a factor. It depends on the relative placement of the center of gravity to the aerodynamic center of pressure and the normal force which is trying to tumble the bullet (C_{np} in C_{np}/C_N , a (normal force coefficient) X (separation between the center of gravity and the center of pressure in calibers)). The shape of the ogive and the velocity of the bullet affect the pitching moment coefficient. The best example I can think of for understand the pitching moment is to think of turning a wheel on an axle. The axle represents the bullet center of gravity and the point at which the normal force is applied represents the aerodynamic center of pressure. The force applied to turn the wheel is the normal force. Trying to turn the wheel by applying force to its outer edge (larger pitching moment) takes less force than closer to the axle (smaller pitching moment). We can now understand why a large separation between a bullet's center of gravity and its center of pressure will make it easier to tumble.

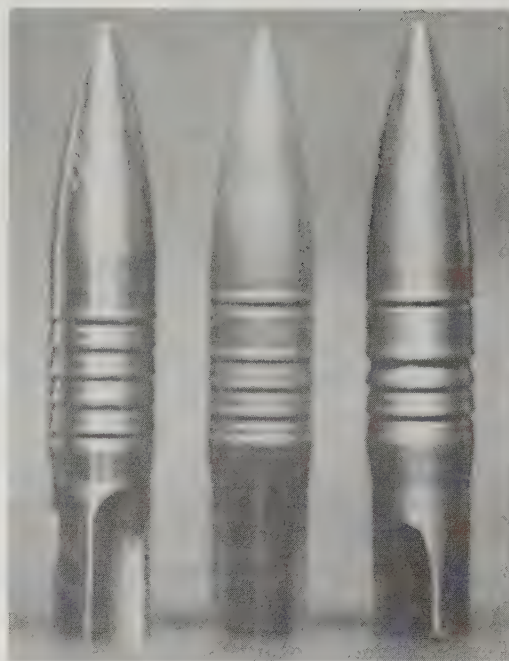
As a rule of thumb, bullets with longer radius ogives will have lower pitching moment coefficients and therefore, will possess higher stability factors. This is because longer radiuses result in lower normal forces and cause the center of pressure to move rearward closer to the center of gravity. In fact, conical ogives result in the highest stability factors while round nose bullets would have the lowest stability, with bullet length held constant. Also, increasing boattail angles will slightly increase the stability factor.

As a bullet's velocity decreases while it travels downrange, the normal force also decreases and consequently, the pitching moment coefficient decreases. Since the velocity decays much faster than the bullet spin, the gyro stability factor will always increase downrange. Therefore, one really only needs to be concerned about bullet stability at muzzle conditions. An interesting design feature of some limited-range training bullets was the placement of a fin-like structure in place of a boattail. These fins caused the spin to decay at a fast enough rate such that the stability factor would decrease below 1.0 somewhere downrange, and the bullet would begin to tumble, limiting its range.

The diameter factor in the denominator of the equation is somewhat misleading since it is canceled out by the dependency of the axial moment of inertia, in the numerator, on diameter. As most know, larger caliber guns generally require slower twist rates in inches per turn. However, the required spin rate in calibers per turn is nearly constant for all bullets.

To understand dynamic stability one must understand the precession and nutation of a spinning body. The behavior of a spinning top is the best way to visualize the motions of precession and nutation. If a spinning top is placed on the ground with its axis of spin at any angle other than straight up, it will precess with its axis of spin tracing out the outer surface of a cone. Quite often the top will not precess smoothly but it will wobble as it traces out a cone. The wobble is called nutation. Similar forces that cause the top to precess and nutate apply to a spinning bullet and it, too, will exhibit the motions of precession and nutation. With a bullet it is desirable to have the motions of precession and nutation decay as it flies downrange. In the language of shooters the bullet should "go to sleep." Precession and nutation cause an increase in drag.

The dynamic stability is a measure of how fast and synchronic the precession and nutation frequencies decay. PRODAS calculates a dynamic stability factor which must be between 0.0 and 2.0 with a dynamic stability factor of 1.0 being ideal. It is possible to concoct bullet designs in which either the precessional or nutational motions grow, but this is usually not a problem, unless excessively long boattails or ogives are used. Sometimes a dynamic stability problem is encountered downrange when a bullet goes transonic. PRODAS can analyze the dynamic stability of a projectile over its complete trajectory. PRODAS will also calculate both the individual mutational (L1) and precessional (L2) damping coefficients. The bullet designer must be sure that both L1 and L2 are negative to assure these motions will decay.

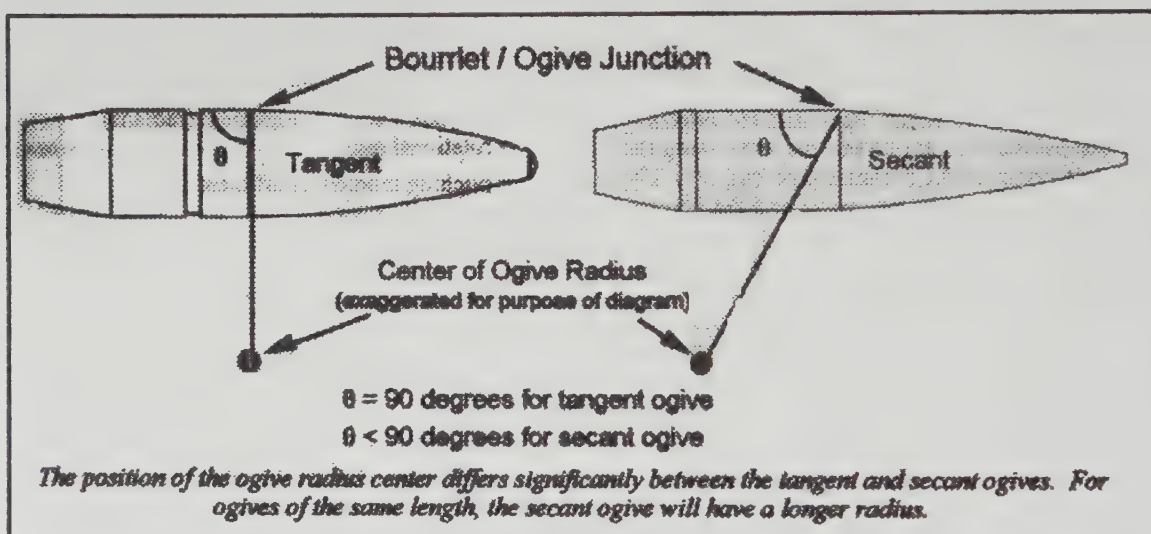


Finned limited range training bullets designed such that gyro stability decreases downrange due to a rapid decay in spin.

As an example of a bullet with a dynamic stability problem, a probe-nosed limited-range training .50-caliber projectile has been designed by Aircraft Armaments Inc. (AAI). This projectile has a very low dynamic stability factor which goes negative a short distance downrange. In effect the precessional motion of the projectile continues to grow until it is no longer stable.

Bullet Design and Ballistic Co-efficient

It's now evident that all one needs to do is to increase sectional density and decrease the form factor of a bullet to maximize the ballistic coefficient. The major limitation to increasing ballistic coefficient is the stability factor. Longer bullets will have higher sectional densities but will also have lower stability factors. One meets a limit for ballistic coefficient which is very close to being linearly proportional to caliber. Simply put, a fifty caliber projectile can have a maximized ballistic coefficient which will be twice that of a maximized twenty-five caliber projectile. The ballistic coefficient versus the stability factor is the greatest tradeoff a small-arms bullet designer will encounter.



A bullet designer must also be aware that the sectional density and the form factor are usually dependent upon each other. The only way to change the sectional density without changing the form factor is to change the bullet's material of construction. If one tries to modify the form factor by changing the ogive or boattail dimensions, one will invariably change the sectional density simultaneously. The point I'm trying to make is that one really needs a computer program like PRODAS to find where the maximum ballistic coefficient occurs for a particular stability factor requirement.

I can leave you with some general rules of thumb regarding bullet design and maximizing ballistic coefficient. First, choose a bullet length between 5 and 5.5 calibers in length. The ogive should be about 3 calibers in length, the driving band (wheelbase of engraved surface) about 1.5 calibers in length, and the boattail about .8 calibers in length. Depending on the materials and method of construction, the best ogive will be a secant ogive of about 15 to 18 calibers in radius. Higher density lead-cored bullets maximize their BC's with about a 15 caliber radius while solid steel bullets maximize at 18 calibers. This dependency of best ogive radius on material of construction is owed to the dependency of sectional density on form factor, as I mentioned earlier. The meplat diameter is optimal at close to 0.1 calibers. The

maximum ballistic coefficient will occur with a boattail angle close to 8 degrees. Essentially, what I have described is the VLD design concept that Bill Davis of Tioga Engineering has donated to the shooting world. The VLD design is a very good design but one must closely monitor stability factors, especially when one is using low density materials of construction.

I need to mention that in terms of stability, ballistic coefficient, and design opportunities, a secant ogive is superior to a tangent ogive. These two ogives get their names from the geometrical definitions of a secant and a tangent. A secant is a line which intersects a circle at two points while a tangent is a line that intersects a circle at only one point. If one were to continue the radius of a bullet's ogive to make a complete circle and extend the bullet's bearing surface line, they would find that line defining the bearing surface will intersect the circle defined by the ogive at one point for a tangent ogive and at two points for a secant ogive. A conical ogive is a special case of a secant ogive where the ogive radius is equal to infinity.

I believe that the tangent ogive has been so popular over the years with shooters simply because it has a more aesthetic appearance, though the secant design is the performance winner. Until recently, only Hornady has made extensive use of secant ogives. One should note that all the modern military cannon projectiles (20MM to 203MM) also possess secant ogives. According to bullet and die makers, dies used to manufacture secant ogive bullets with small transition radii between the ogive and the bourrelet do not exhibit long tool life; thus, explaining the lack of commercial secant ogive bullets. The junction between a secant ogive and the bourrelet must be sharp for the bullet performance to be consistent shot to shot. If this junction is not sharp, the air flow over the bullet can originate at random points along the ogive. This affects the location of the aerodynamic center of pressure, often times totally ruining the design effort put into the projectile to begin with.

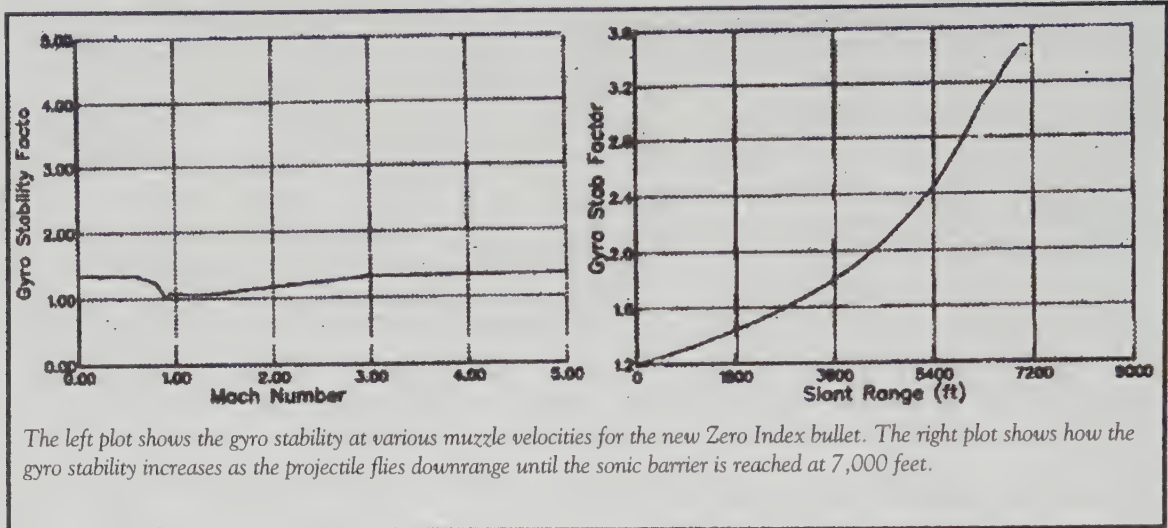
Bullet Design and Dispersion Sensitivity

Projectile related dispersion can result from several sources. Some of these sources are: inconcentric bullets and bullet jackets, initial pitch or yaw angular rates caused by misalignment of the projectile axis about the gun bore axis, dynamic unbalance resulting from a tilt in the projectile principle axis, and bore clearance owed to undersized projectiles (typically encountered in cannon projectiles). Of course, there are other causes for dispersion like: barrel vibration, pointing variations due to thermal expansion, sight error, range error, and cross winds, etc. PRODAS will compute the dispersion exhibited by a projectile resulting from static offset of the projectile center of gravity from the gun bore center line and misalignment of the projectile center of form from the gun bore center line. Different bullet designs will have different sensitivities to these misalignments. It's the projectile designer's job to minimize this sensitivity.

Jump angle (directly proportional to dispersion) is presented in radians. The bullet designer and gunsmith can do several things to reduce dispersion. The transverse moment of inertia should be minimized. This can be done by designing shorter projectiles and projectiles with longer ogive radius uses, and concentrating the projectile mass near the projectile center of gravity. The axial moment of inertia is usually ignored in design considerations since it is usually a factor of ten larger than I_x for spin stabilized projectiles.

The benchrest shooter has some control over S_g , minimizing bullet runout and concentricity, having concentric case necks, and controlling seating depth impact. We can also see that minimizing twist rates (p) will also reduce dispersion. This is where the so called "overstabilization" factor has its negative effect.

The key elements of bullet design to minimizing dispersion are with the pitching moment



coefficient (C_{ina}) and the transverse moment of inertia (I_y). Since this term is in the denominator of the equation, the designer must maximize the pitch moment coefficient to reduce dispersion. This is most conveniently done by moving the center of gravity rearward. An adage of the bullet designer says: "put the mass in the ass." This is one reason match projectiles are hollowpoints. Here again, we have another major tradeoff between dispersion and gyro stability, since increasing the pitching moment decreases the gyro stability. A bullet designer will also have to deal with a major tradeoff between ballistic coefficient and dispersion. This is due to the relationship of bullet length to both I_t and BC.

Method and Material of Construction: An Example in Designing a New Fifty Caliber Bullet

A bullet designer's decision whether to design a traditional lead-cored jacketed bullet or a solid homogeneous bullet will be based upon many factors. Quite often, the required terminal performance and the ease and cost of manufacture will determine the method and material of construction. For fifty caliber bullet designers, other factors come into play. The lack of concentric jackets and the density of lead relative to the fifty caliber bore size has resulted in a predominance of solid, fifty caliber match projectiles.

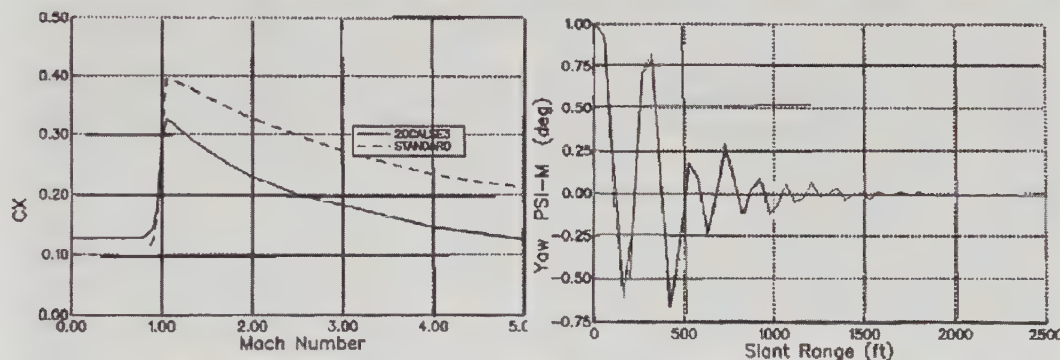
In terms of density, copper alloys tend to be an ideal material of construction for fifty caliber projectiles. Most fifty caliber match projectiles currently being used are either brass or bronze alloys. These projectiles have the problems of severe fouling and rapid bore wear. A way around these problems is to use Ledloy steel as the material of construction and reduce the bullet engraving length as much as possible. The Bieber bore riding bullet design manufactured by Zero Index is an example of this type of bullet. This bullet currently holds the FCSA single target record of 4.034" and the aggregate record of 10.85. The bullet has a .085" driving band measuring .511" in diameter and a bourriet length and diameter of 0.7" and .502", respectively. Shooting this bullet in a standard .500" bore and .510" groove barrel results in only .085" of full engraving with 0.7" of length being engraved only .001" per side. This minimal engraving cuts down on bore wear. The slightly oversized bourriet is engineered into the bullet to avoid any yaw resulting from bore clearance.

Although the use of steel results in a loss of sectional density relative to copper, it doesn't foul. Because of the use of steel and the eight caliber tangent ogive, the Bieber designed bullet

has a ballistic coefficient of only 0.68. We clearly saw room for improvement in the ballistic coefficient. A limitation in designing the new bullet is that it must be stable in the standard 15" twist. Most guns currently use a 15" twist and we wanted the manufacturer, Zero Index, to have a market where they can sell bullets.

Using PRODAS to design a bullet is an iterative process. One cannot ask PRODAS to maximize the ballistic coefficient for a particular twist rate and have it produce the design in one pass. One must start with a good guess for a design and then by trial and error zero-in on the best design. This is not very difficult to do if one has a basic understanding of the principles in this article.

One must choose what minimum gyro stability factor is acceptable. Quite often a gyro stability factor of 1.5 is used as a target. The Bieber design has a gyro stability factor of 1.42 in a 15" twist at standard atmospheric conditions. We decided that a gyro stability factor of 1.2 would be the minimum acceptable value. This would give a margin of stability that would be useful in colder atmospheric conditions and, at the same time, would give us some room to improve the ballistic coefficient.

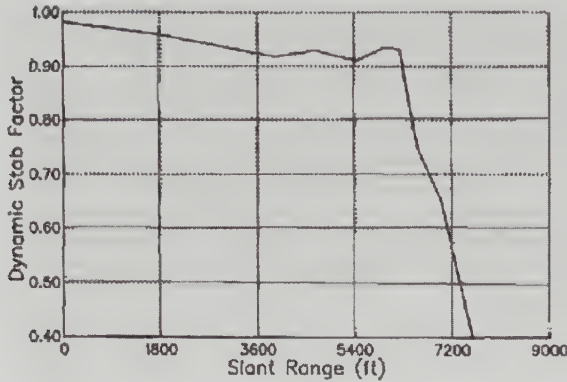


Left plot shows the comparative drag of the old and new Zero Index designs. Actual drag can be obtained by multiplying the drag coefficient (CX) by the bullet frontal area, the air density, and the velocity squared. Notice how the drag coefficient increases rapidly around the sound barrier. Right plot shows the simulated yaw decay with an initial one degree of muzzle yaw. According to PRODAS, the bullet has "gone to sleep" around 500 yards.

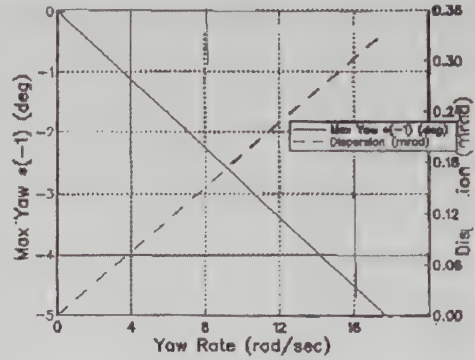
After using PRODAS to analyze bullets of different lengths, it looked as though 2.8" in length would be the maximum we could use and still keep the gyro stability factor above 1.2. Using VLD design principles with a steel bullet of 2.79" in length did not result in satisfactory gyro or dynamic stability. Our next adjustment was to increase the radius of the ogive from 15 calibers to 20 calibers. This resulted in an increase in both ballistic coefficient and gyro stability, although we still weren't quite where we need to be with gyro and dynamic stability. By increasing the boattail angle from 9 degrees to 12 degrees we gained the needed gyro and dynamic stability but lost some ballistic coefficient.

By increasing the boattail length from .8 to .9 calibers we gained back some ballistic coefficient without much of a negative impact on the stability. This example of the iterative design process with PRODAS resulted in a bullet weighing 723 grains; only a 3 percent increase in weight from the original Bieber bullet, but an increase in ballistic coefficient from 0.68 to 0.99, or a 45 percent increase. In a 10 MPH crosswind the old design will deflect 63

inches over a 1,000 yard range when fired at 2700 ft/sec. The new design deflects only 40 inches when fired under the same conditions. The new bullet has a gyro stability factor of 1.22 and a dynamic stability factor of 0.98 at a muzzle velocity of 2700 ft/sec. While the bullet has an unconventional, long 12 degree boattail, there is nothing arbitrary about its design. It is very close to the optimal design for a steel bullet in a 15" twist.



PRODAS will plot the dynamic stability factor as the bullet flies downrange. In this case, a dynamic instability problem is evident around 2,000 meters. This happens to be the transonic range for this bullet/velocity combination. This behavior is not a rare occurrence and is useful to know for the ultralong-range shooter.



Based on the amount of yaw at the muzzle one can predict the amount of dispersion expected for a particular projectile. From the yaw on the left axis go across to the solid line, then down to the dashed line, then right to read dispersion. This plot is calculated from the dispersion sensitivity of the projectile.

With only a minimal amount of testing completed, the only thing we can say is that the new bullet is gyroscopically stable when fired from a 15" twist barrel. The new bullet saw some use in the recent FCSA National Match with good results, but more data will be needed before we know if we have a winner. The new bullet is now available from Zero Index, 9900 Sierra Way, P.O. Box 234, Kemville, CA 93238 for \$1.50 each. Buyers must beware that this bullet is still considered experimental and we have had a few reports of excessive yaw, possibly resulting from muzzle brake effects.

DETAILS ON PRODAS

PRODAS already has a list of successes to its credit. Olin has used PRODAS to design projectiles for their "Supreme" line of Winchester ammunition. Federal used PRODAS in development of their Olympic winning "Ultra-Match" .22 caliber rimfire ammunition. Remington has used it in the development of their line of "Extended Range" ammunition. Along with these cases, there are a myriad of military uses of PRODAS for the development of cannon ammunition in both government and defense contractor labs.

Since PRODAS uses a significant amount of empirical data collected from measurements on over 100 test projectiles, small errors can exist. Arrow Tech Associates claim that the major aerodynamic forces and moments important to prediction of projectile flight behavior can typically be predicted by PRODAS to an error of less than 5 percent.

There are many other things which PRODAS can do that I haven't even mentioned. These other types of analysis include: fin stabilized projectiles, tracer projectiles, interior ballistics, driving band wear, moving platform, and armor penetration. Although these

additional analysis have use for mostly military applications, they make PRODAS an impressive package.

Now, for the punch line, PC-PRODAS sells for \$5,000 a copy. It's a lot of money for a computer program, but a good buy when you consider what it costs a bulletmaker to tool up for a new design; especially, when that new design might have some major flaws. I'm a believer in computer modeling. In my profession we use computer modeling to study chemical processes before we build a manufacturing plant. In the chemical manufacturing business, a \$20,000 chemical modeling program is much cheaper than a mistake on a \$20,000,000 plant.

Arrow Tech Associates has plans to market a lower cost version of PC-PRODAS to reach other markets such as the smaller volume bullet maker. Arrow Tech plans to eliminate most of the military type analysis for the lower cost version but the important bullet flight analysis will remain. For the latest details on PC-PRODAS or the new low cost version write: Jeff Siewert at Arrow Tech Associates, P.O. Box 421 8, S. Burlington, VT 05406. The author is grateful to Jeff Siewert and Arrow Tech for the extensive education on bullet design they have provided me.²⁵

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PART IV: WILDCATS

The next section is about the different custom .50-caliber bullets that are on the market. Some of these designs have been updated and certainly there are some that have been missed along the way. Two of these designs are by commercial manufacturers that already have well established reputations in their common fields of ammunition production. The rest are from smaller and more customized shops. These special bullets are the result of the efforts previously mentioned in this chapter. They represent the fine ability that is in this country today in research and development, and done at many times without the aid of super fast computers that only government agencies have. Yet, these are some of the best bullet designs in the world.

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THE CUSTOM BULLETS

Hornady AMAX 750 Grain Bullet

The Hornady AMAX 750 gr. match bullet has been around since 1994. It was introduced at the 1994 SHOT Show. In the picture (on the next page) you can see the design change that has occurred between 1994 and the current bullet on the right. In the center is a .308 caliber AMAX match bullet (red tip). The bullet is a standard jacketed bullet that is fully engaged by the barrel's rifling as in the conventional bullet design. The bullet is in three parts. The (1) jacket is about 2.1 inches long and about .06 thick. (2) the lead core and (3) an aluminum tip. Notice the difference in the aluminum tip from the previous release of 1994. The aluminum tip serves to move the majority of the weight mass towards the rear end of the bullet. This lowers the dispersions sensitivity. Eric Williams calculated this sensitivity to be 40 percent less than a bullet than a solid copper bullet with the same amount of misalignment or runout. (Remember that need from the previous article on bullet design?) The calculated ballistic co-efficient is listed as 1.050 at the Hornady website. In early tests from a M87 rifle, the bullets apparently were able to hold less than 1 MOA groups at 100 yards. The bullets are designed to be shot in standard 1:15 twist rate gun barrels. An interesting note is that the aluminum tip reportedly has a pyrotechnic flash when impact metal targets. In volume, Hornady is the largest producer of match grade .50-caliber bullets in the industry.

The Barnes 750 and 800 Grain Match Bullets

The Barnes bullets have been around for a while and are some of the most successful bullets on the market. The calculated ballistic co-efficient is 1.07 for the 750 grain bullet and 1.095 for the 800 grain bullet. Both bullets have a narrowed section of the bullet that has two purposes. First, there is less bearing surface to wear the barrel of the gun. More importantly, however, is that the narrowed surface is done with the intent of invoking the venturi effect. This is the same effect that gives airplane wings lift. As the air passes over this narrowed section, it is slightly accelerated. This has the effect of lowering the overall drag on the bullet. The design must work. Note the slight difference in the BCs for the Hornady 750 grain bullet and the Barnes 750 grain bullet. The bullets are CNC machined out of solid bronze with no lubricating substances impregnated into them.

These next two sets of bullets were made a few years ago. Charles Poff designed and made two bullets out of solid beryllium copper. The smaller bullet is a 300 grain .358 caliber bullet of Very Low Drag (VLD) design. The bullet was made for a project that necked down a .50-caliber cartridge case to .358 caliber. The CI ballistic co-efficient for the .358 caliber bullet is .845 for a velocity range of 1100-2900 feet per second. The high BC is .936 at 2900 fps, with a low of .635 at 1200 fps. The .358 caliber bullet has only 40.85 inches of wind drift at 1,000 yards from a muzzle velocity of 2900 fps. Remaining velocity at 1,000 yards is 1935 fps. No ballistic information is available for the .50-caliber bullet. It is not known the extent of the production of these bullets, but they provide a good historical reference. The information on these bullets is dated from 1989.

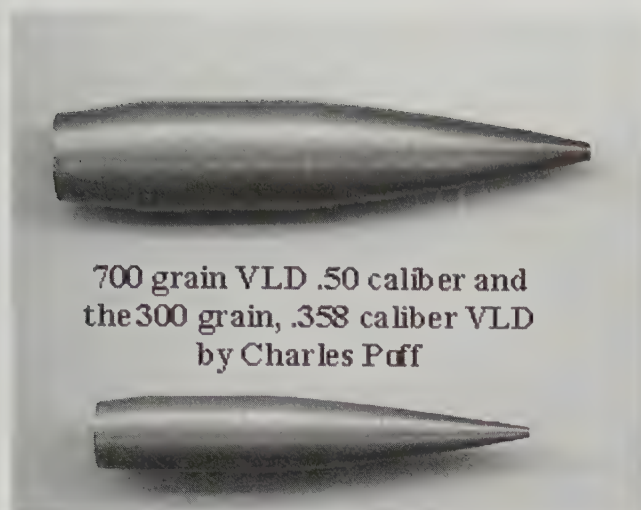
Horstkampt 764 and 500 Grain Bullets

The Horstkampt 764 and 500 grain .50 caliber match bullets are also some of the earliest design of



The Barnes
750 gr. LRS.

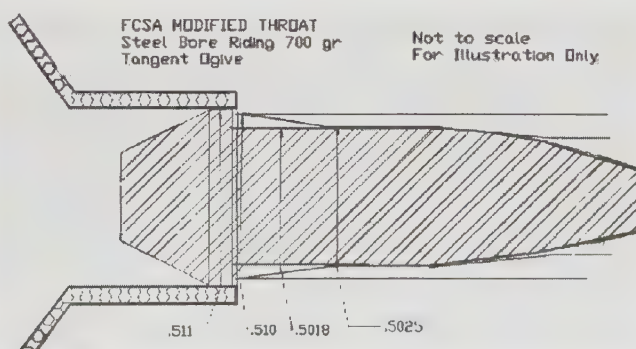
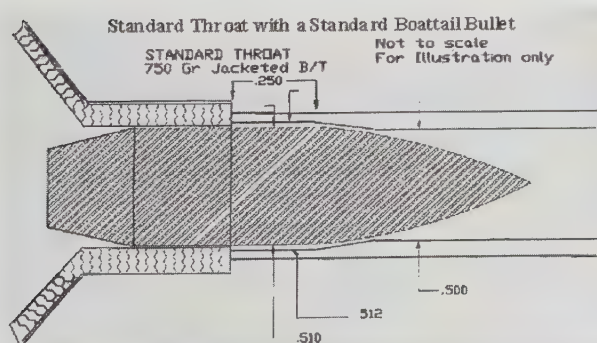




machine turned bullets. The interesting part of the 764 grain bullet is the use of three different angles on the boattail. The multiple boattails were intended to handle the drag over the tail of the bullet at different velocities. The theory was that a different angle came into effect as the bullet changed velocity ranges. The nose of the bullet is of a more conventional design and is not considered a VLD bullet. The bronze are made of bronze and are impregnated with silicon to provide lubrication for the barrel. Earlier versions of these bullets were impregnated with a lubricating oil. That was a problem for tactical shoots as the heated oil left a smoke trail back to the shooter's position, hence the change to the silicon. The listed ballistic co-efficient for the 764 gr. bullet is .6880. The surface of the bullet is engraved with multiple bands. This is NOT a bore-rider design and the bullet is intended to engage the rifling. The engraved bands are to reduce the wear on the bore, yet retaining the longer bearing surface.

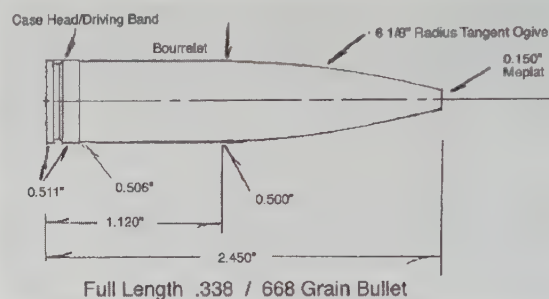
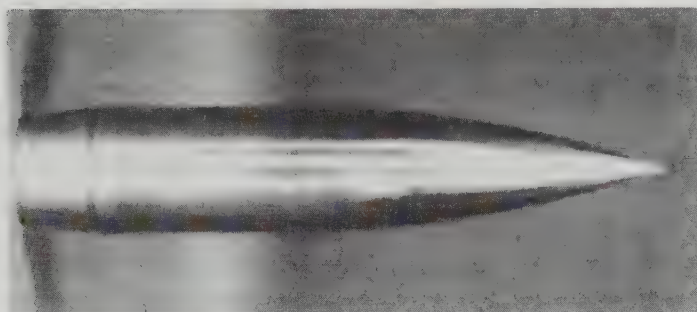
The bore riders require a bit different throating in the barrel than the standard bullets require. The bore riders are at times referred to as the Bieber or Mance bore rider design whole class of bullets that are called "bore-riders." The standard bullet throat²⁶ starts at a diameter of .512" and tapers on a 1.5 degree angle for .250" until the throat runs out of land on this angle at a land inner diameter of .500".²⁷

The throat that is cut for the Zero Index 700 grain bore rider is considerably different than a standard throat. The steel bullets from Zero Index had (at that time, 1994) a driving band that was .085" long and was .511" in diameter. The body of the bullet in front of the driving band was centerless ground to a diameter of .5018".



Mance 765 Grain Bullet

Another bullet that deserves mention here is the Mance 765 grain bullet. The "Windrunner" rifle set a record with this bullet (date and data are unknown). The claim by First Defense personnel that shot the gun was a group of 1/4 Minute of Angle at 1004 yards. The load was 253 grains of N-29 at a muzzle velocity of 2878 fps. In a discussion during the research of this book, Mr. Mance stated that he had not made these bullets for more than a year, but was willing to begin production again if the market looked good. Note that the general appearance of this bullet is the same as the Barnes, Zero Index and the berrilium copper bullets from American Arms. Appearances are deceiving though. The Mance, Zero Index and Barnes bullets all held records at 1,000 yards at one time or another. It would appear that the record moves from one bullet manufacturer to another shortly after a new record is set.



This next bullet is a presentation of a concept that is being used pretty successfully as of late. The information and photos are from a 1994 article. The concept involves using actual rifle brass, that is swaged down and turned into a bullet jacket.²⁸ The designer of this bullet makes five very good points in bullet design that resulted in this bullet design. The comments are condensed by the author.

1. Canadian Ball projectiles punch forming dies for the jackets had longitudinal splines machined into them. The resultant grooves in the jacket forced the jacket to tightly grip the core of the bullet. This insured that the jacket and core were locked together and didn't result in two different components of the bullet rotating at different RPM while the bullet is accelerating.
2. Casting a lead core bullet inside of a smooth jacket will result in the above action. A bullet having this occur will be unstable in flight and slow down faster until the RPM of the core matches that of the bullet.
3. The bearing surface of the bullet in front of the driving band to the front of the bourrelet should be long enough for perfect alignment with the barrel centerline. The designer of this bullet likes a 1" bearing surface.
4. Case heads on unfired belted magnum brass measure about .528" and normally run anywhere from dead true to .008" out of concentricity to the body. This band should be turned down to fit the groove diameter of the barrel on your gun. You should get the case of the bullet turning with .0002" before turning the band to size.
5. Obtruating pressures for solid bronze bullets with full length .511" bodies can be quite high. One reason I use prefer unfired brass to using fired cases is the fired case can measure as much as .515" just ahead of the case head. Unfired cases measure about .506" at the same point.



Top: From .338 Mag. brass to .50 caliber bullet through a series of stages.
Right: 668 grain bullet from a .338 Mag. case and a 726 grain bullet from a .300 Mag. case.



The designer was using #9 (.080 diameter) lead shot for core material. Tungsten carbide shot should provide significant gains in sectional density and ballistic co-efficient, the price is high for this material and the availability is low.

To address the question "How tight is the shot mass inside the jacket?" I do not sell or use any projectile that will not roll slowly across a desk top or surface plate in a manner similar to a match grade solid. To explain, take two unfired empty .338 cases. Fill one about half full of #9 shot and seat a bullet. Try to roll it slowly. It will not roll very far, maybe not at all. Fill the other one full to the mouth, vibrate and tap to settle shot and seat a bullet to lightly compress the shot. This one should roll very smooth and steady. Exceptions will be an out of concentric case or cheap non-uniform shot that loaded out of balance. I am not saying that the best shot filled projectiles will perform as good as match grade solids, but they certainly do shoot well.

To explain what I think is happening, the 0 to 2,800 fps acceleration in less than 31" is pushing the shot to the back of the jacket while the 134,000 RPM (1 in 15" twist at 2,800 fps) is pushing it outwards so hard that the shot is effectively locked to the jacket. So far, I have seen no evidence of yawing projectiles, no skid marks in the brake and no elliptical holes in paper targets. My brake has a .531 "X 6" long hole with 40 of 3/8" diameter ports venting 40 degrees rearward from perpendicular to the bore. I have shot 7 1/2" 3 shot groups at 800 yards with these bullets.

Until somebody proves them at a match, what I say does not count for much. I do not expect they'll displace the Zero Index bullets now in use. Landing one of these on target or even a touch short generally means you need a new target.

Cost-wise, I do not think we have gained much but they do have one big advantage over solids. When they hit your target they disintegrate very rapidly. As a result, they have almost zero armor piercing ability.

I presently use only full length unfired .338 Winchester Magnum brass. This ends up as a 668 grain X 2.5" long bullet. The ogive has a 6 1/8" tangent radius with a .150" diameter

meplat. The bourrelet is 1 1/8" long and tapers from .500" at the ogive to .506" in front of the case head/driving band. I use 225 grains of H5010 or 230 grains AA 8700 to drive them. Producing these jackets requires a strong press. The biggest disadvantage to these bullets is the need to turn the case head on each and every one. I use the following procedure to produce my 668 grain shot filled bullets.

Case mouths must be perfectly round and bodies must be free of dents. The amount and distribution of case lube is more critical than you might think, a real pain at best.

Cases are swaged into jackets in .071" increments. The first die leaves a 1/4" neck on the nose of the bullet to load the shot into. After total weight (jacket + shot) is achieved to the desired tolerance, the cases are vibrated to settle the shot. The nose is then closed with the second die.

I seal the meplats with a hot melt glue gun before sealing the flash holes with a spent primer.

Case heads are turned to fit the uses groove diameter.

I give the bullets a final weighing and then roll them across a surface plate to eliminate any rejects.²⁹

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I have tried to cover as many of the specialized bullets as possible. Some requests for information have gone unanswered and messages left on answering machines were not responded to. Those that have are in this book. As of yet, there is no consideration going on within the military on the white side of special operations (the active and reserve Special Forces Groups, Ranger Battalions, etc.) for these specialized bullets. For some reason, there is this dominating need for the bullets to be explosive and tracing and incendiary. I would disagree with that analogy in many hard target cases. By ignoring these specialized bullets, purchasers are saddling operators with ammunition that is certainly going to result in mission compromise on the first (and possibly unsuccessful) shot.

PART V: RELOADING

This section is on reloading the big .50 caliber cartridge. This can be a dangerous undertaking if one is cutting their teeth on reloading by reloading this cartridge. It is NOT recommended that someone with little experience try this craft. The following article by Eric Williams explains some of the dangers quite well. Of all the cartridges that can be reloaded, this one has the greatest potential for disaster if extreme attention isn't paid to the contents of the following material. This section is loaded with warnings and safety precautions. Please read and re-read these items. If you are going to reload for a .50 caliber gun, contact the manufacturer first for data. Also the FCSA will provide any help as they have probably already reloaded for you particular rifle, military or civilian. Reloading these cartridges is NOT like doing a .45 ACP or a .308 round. Mistakes made here can have fatal or maiming results.

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A .50 BMG LOADING GUIDE by Eric Williams³⁰

One of the first things learned about fifty caliber shooting is the universal fact that .50 BMG ammunition is not found on your local gun dealer's shelf. Surplus supplies come and go, and the

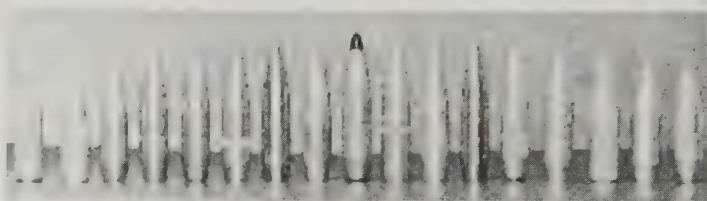
supplies of some commercial reloaders are often depleted. These facts lead to aggravation for most fifty caliber shooters. Most shooters will eventually turn to reloading as a reliable source for ammunition. Added to the availability problem, the need for match quality ammunition sends those wishing to be competitive to the loading bench.

Over the years I've been involved with this newsletter, I've been aware of the two major shortcomings of the *Very High Power*: the lack of product test data and loading data. Turning our attention to the lack of loading data, there are several rational reasons this has been. First, we had to assure that our experience in loading was ample, accurate, and well tested before passing it to others, especially those with less handloading experience. Second, the legal nature of things these days makes it prudent that you give nothing out which can in some way be used against you.

As you might have already gathered from Skip's previous article in this issue, there has been some alarming evidence that some reloaders were operating at the brink of disaster. Keep in mind, when you're dealing with four to five the powder charge of typical highpower rifle cartridges, you are truly talking about a potential disaster. Now, to make matters worse there are many handloaders gaining their first loading experience on the .50 BMG. This is understandable since everything else they previously shot was obtainable from some retail outlet, and the fifty, because of the ammo availability problem, forced them to start handloading. Gaining handloading experience involves many aspects beyond what you can just read about in any manual. Two important aspects are being able to recognize the signs of high pressure and realizing there are too many variables to make any load good for all guns.

With my past articles on bullet, brass, powder, and primer variations, I've been building to the point where I can distribute some loading data with the understanding that readers will comprehend the variables involved. Loading the .50 BMG is not a recipe type of affair. After loading over 3500 rounds of fifty caliber ammunition that I have personally shot through six different rifles over the past eight years, I concluded that a good loading manual for the .50 BMG cannot exist. Why is this so? To put it succinctly, the range of variation in guns and components far exceeds that found in smaller arms.

I want to take you a little deeper into understanding these variations; especially, the variations of greater magnitude than those found in smaller arms and their components. In weighing brass over the years, I've found as much as 100 grains variation in weight. Knowing that your rifle chamber has a constant volume and assuming the various makes of brass have the same density, 100 grains of brass translates into about 12 grains of powder volume. Twelve grains of powder is about 5% of the total. As a rule of thumb, for every percentage of powder increase we can expect a two percentage increase in pressure. Therefore, we can estimate that



Variety abounds in both bullets and brass.

the variation in brass weight can contribute at least a 10% variation in pressure. This is a variation that is encountered in close to the same magnitude loading smaller arms; most often in going from commercial to military brass.

Moving to bullets we can find a big and possibly the most important difference between loading the fifty and smaller cartridges. This difference is owed to the construction of most fifty caliber bullets versus the typical jacketed lead-cored bullets of the smaller variety. The reasons bullets are constructed differently for fifty caliber are the subject of another article, but their effects on pressures are important to know for the handloader. The steel-cored and solid copper alloy fifty caliber projectiles do not behave like a lead-cored bullet when placed under the stresses of firing. A lead-cored bullet will conform to the dimensions of the bore, by either obturating or swaging. A steel-cored or copper alloy solid bullet will not obturate or swage as much, if any, to the dimensions of a bore. In short, pressures will climb dramatically quicker when these bullets become oversized relative to the bore. I'm not going to begin to guess the percentage of variation we are dealing with here, but I feel that 25% is a conservative estimate.

I ran some experiments several years ago with some TCCI 75-grain bullets. I had a batch of each undersized and oversized projectiles and ran a test to see what differences could be found between different dimensions of the same projectile design. For an increase of .001" in bullet diameter, I got an average increase in case head expansion from .0003" to .0005". That's a 67% increase in head expansion. I'm not sure that head expansion correlates directly with pressure, but you can bet that the pressure increase was significant. You might be able to avoid this variation by culling (weighing each bullet and placing them in lots of like bullet weights) your bullets, but you can't change the dimensions of your bore. The first shot with a new bullet in a tight bore may be the one that gets you in trouble.

I need to add that for military barrels the specifications allow a variation of .0025" in bore and .004" in groove diameter.³¹ Try forcing a .512" steel bullet through a .509" grooved bore and you'll get some high pressures with what would be considered mild loads. My advice here is to build your gun with new match grade barrels only. Save the surplus machine gun barrels for what they were intended for—machine guns. My feelings about putting a military barrel on a good, expensive match grade action would be similar to feelings about feeding strawberries to a jackass.

Another variable that can't be avoided is changing bore dimensions resulting from barrel wear. We've found that fifties shooting solid bullets tend to wear barrels by expanding their dimensions. In fact, a worn barrel can measure .004" larger than when it was new. To give you an idea of what this means to the handloader, I've found that my .50 BMG Improved loads will call for as much as 30 grains more powder in a worn barrel than in a new barrel, just to maintain original velocities! If I were to use the same loads that I use in an old barrel in a new barrel, I'd wreck the gun.

Two issues ago we discussed the subject of powder lot variations. This is another area where we can have trouble for which a reloader using canister grade powders doesn't have to worry about. Here we found variations of around 7% in velocity going from one lot of the same powder to another. This would translate into at least a 15% variation in pressure.

Primers are addressed later in this section, and from the data collected during that test I would expect pressure variations around 10% in switching primers. Keep in mind that loading manuals don't give duplicate sets of data for different primers, so, this is another variable that we have to be cautious about changing.

There are other variables that I'll list which can significantly effect pressures. These can be: throat variations, barrel surface variations, powder distribution differences in the case, primer seating depth, bullet seating depth, bullet bearing surface area, and temperature. For

temperature, if you work your loads up at 30 degrees F and then shoot them later at 85 degrees F, you can expect an increase of about 12% in pressure. In looking at differences in the powder distribution within the case, Hatcher's Notebook offers some data on fifty caliber rounds which were fired in a position of primer up or down. They found an increase of 4,000 psi (9%) when the primer was positioned down relative to up. In the new Barnes reloading manual Dave Scovill, Handloader editor, is quoted to finding velocity variations of 100 ft/sec by just varying the primer seating depth. Of course, velocity variations indicate that pressure is also varying.

[For those interested in a treatise on pressure factors, I thoroughly recommend the book *Firearms Pressure Factors* by Lloyd E. Brownell and published by Wolfe Publishing Co., 6471 Airpark Drive, Prescott, AZ 86301. This book presents some interesting empirically derived formulas that allows one to quantify the effects of many variables presented above.]

Adding up these variations one will find that loading fifties can be dangerous if done haphazardly. This is why I believe that listing loads, like done in common loading manuals, would not be a prudent thing to do for fifty caliber reloaders. I feel that a loading guide is a better way to teach reloaders of fifty caliber than a loading manual. A manual is something that tries to say "do it like this and you'll get these results;" whereas, a guide tries to show you how to develop your own results.

One item people like about manuals is knowing ahead of time what velocity can be expected from a particular load. Velocity is always an important criterion to a handloader when choosing a load. That's why loading manuals are expected to contain velocity data, although it is usually misleading. The chances that you'll get the velocity that the manual claims are slim. Because of the additional variables in fifty caliber reloading, the chances would even be slimmer that a fifty caliber load would yield the manual's velocity. Consider, also that fifty caliber barrels are found from about 24" to 45" going from compact rifles to machine guns. A difference of 21" in barrel length would translate into a difference of 300 to 350 ft/sec in velocity with the same load. Hopefully, you can now understand why I say that a good loading manual for the .50 BMG cannot exist.

I hope to provide a set of guidelines that will allow anyone to safely develop a .50 BMG load for any sound rifle. In using these guidelines you will have to become more involved in handloading than just following a recipe. You will need to know when a safe maximum pressure is achieved for any particular component/rifle system you're working with. This is why I recommend that only experienced and cautious handloaders assemble .50 BMG rounds.

The guidelines below are the best that I can offer with my eight years of experience loading this cartridge. Even with this experience, I have not witnessed everything that can go wrong, and I cannot control all the variables that you may experience. Therefore, if you use the information offered below it is at your own risk.

1) Any weapon of unknown origin or condition should first be certified as safe by a competent gunsmith. Always, before every firing session the bore should be checked for obstructions.

2) Get some reputable commercial ammunition loaded to nominal specifications. PMC, TCCI, or other manufacturers listed in the FCSA Suppliers List are recommended. Fire this ammo in your rifle before you attempt to shoot your own reloads. This ammo is loaded to known pressure standards and will indicate if your gun has a tight or rough bore which will produce unusually high pressures. One of the best indicators of high pressure with the .50 BMG round in bolt action guns is difficult bolt lift and case extraction. Primer appearance can help but its also misleading because of variations in headspace and primer cup hardness. Cratered or flattened primers with difficult extraction are certainly indicative of high pressure. Semi-autos may show excessive pressures by case rim damage, extraction problems, or the action cycling with excessive force. If you get high pressure with a commercial load, have your

gun's bore and chamber dimensions checked. Undersized barrels should be replaced by a match grade barrel of nominal internal dimensions. Do not use the following guidelines until pressure problems with commercial ammo are rectified.

3) You can use any of the following powders which have similar burning rates: IMR5010 (AA5010 & H5010), WC870 (T870 & AA8700), WC860 (RVO 57, T5020 & AA8600), WC872, T5070, HC- 30. Choose either the RWS or CCI primer and any bullet of nominal diameter (.510"). Any cartridge brass that has been trimmed to 3.91" or less and is free from cracks or corrosion will suffice.

4) The key to developing any load is the starting powder charge. Use the following starting charges based upon the weight of bullet you decide to use. The following charges are not overly conservative. Some may find that their top loads are near these charges.

Bullet Weight	Starting Charge
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650 Grains	210 Grains
700 Grains	205 Grains
750 Grains	200 Grains
800 Grains	195 Grains
900 Grains	185 Grains

5) Without changing any components increase the powder charge by 5 grain increments until signs of high pressure are noted. At the point you notice difficult case extraction, a charge of 5 grains less should be considered maximum. A load of 10 grains less is even more desirable since longer brass life will be realized at lower pressures. If at any point you notice that your primer pockets are getting loose within a few reloads, your loads are too hot. Depending on your set of variables, you may find that your maximum load will be from a few grains to as much as forty grains above the starting charge.

6) If you change primers, brass, or seating depth drop your charge by 10 grains and work up to the maximum again. If you change the bullet, powder, or gun restart your load development, again from the starting charge.

7) Investing in a chronograph is a wise investment when doing load development. Excessive velocities are indicative of excessive pressures - no free lunches here. The chronograph will also make you aware of the constant changes your barrel experiences as it wears. As an added bonus, you'll be able to calculate accurate trajectories for your rifle if you know your load velocity. For the typical sporting rifle with a barrel length of 28" to 32", you can expect velocities for your top loads to fall within the ranges shown below. If you are outside these ranges, then your chamber pressures are probably outside nominal working pressures.

Bullet Weight	Expected Velocity 28-32" Barrel
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650 Grains	2700 - 2850 fps
700 Grains	2650 - 2800 fps
750 Grains	2600 - 2750 fps
800 Grains	2500 - 2650 fps
900 Grains	2350 - 2500 fps

8) You should keep written records of all your loads - never rely completely on memory. If you should find any discrepancies with the above guidelines, please inform the FCSA of your findings. Shared information is the heart of your association. If you have any questions about any other details of reloading, please call one of your FCSA consultants as listed on the inside front cover of the VHP.

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For those that have done reloading with other cartridges, note the different cautions that the author raised concerning sizes of bullets and bores, the effects of a worn bore, and the dangers of using machine gun barrels for precision rifles. The following article by Skip Talbot brings up some more warnings.

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FAMILIARITY BREEDS CONTEMPT

by Skip Talbot³²

Several things have come to my attention through conversations with various individuals in the Association that together call for some alarm. Foremost among these is the misreading of pressure signs during load work up. Also, there are some muzzle brake problems that seem to be occurring for unknown reasons that need to be looked at. These are not catastrophic, immediately, but members should keep these caveats in mind when working loads and shooting.

Both Ken Johnson of K&P Guns and Rock McMillan of McMillan Bros. are seeing signs of excessive pressures as evidenced by returned actions because of bolts broken off in trying to extract a fired round. The bolt handle is stiff, so a larger lever is used such as a hammer and the result is a bolt handle separated from the bolt body.

The usual comment is "THE PRIMER DIDN'T SHOW A FLATTENED SIDE OR THE FIRING PIN INDENT WASN'T PUSHED OUT OR CRATERED!!!" This is most often when the individual is using the CCI #35 primer. THESE PRIMERS ARE NOT THE STANDARD THICKNESS IN THE CUP. This is one reason that a full length sized case is sometimes hard to ignite in some rifles. These thicker cupped primers are harder to ignite and will not show pressure signs before the brass starts to flow. You will probably get a shiny spot on the rear of the case with a STIFF bolt feel upon extracting the fired case. When you feel this, IT IS TIME TO BACK OFF THE LOAD, YOU ARE CLOSE TO LIMITS. This is especially true if you are working up loads at low temperatures that will probably be fired on hotter days. What is marginally ok at 32 degrees F is not going to be pleasant to extract at 80 degrees F next summer.

This is enumerated untold times to the average reloader who will start 10% lower than the max load in his 7MM Rem. Mag and then creep up to the max load 1/2 grain at a time until he either has BOLT FEEL, BRIGHT SPOT ON THE REAR OF THE CASE, WEB EXPANSION OVER 1.5 THOUSANDS OF AN INCH, OR FLATTENED AND CRATERED PRIMERS!! For some reason or another some shooters of the 50 BMG have misunderstood the pressure signs that are apparent because of the lack of a pierced, cratered or flattened primer. BOLT FEEL IS AS A RELIABLE CRITERIA OF PRESSURES as is the flattened primer. The problem is that we have been getting away with it for awhile and no one has had a wreck, but we've been fortunate that the engineering of Rock and other

manufacturers have been adequate to cover our mistakes. Don't bank on it for the long term. Back off the load at least 3 grains from the point you get enough bolt feel that is any kind of strain to unlock the bolt. Don't count on that heavy "click" when you hit the final unlocking cam that's the last 20% of the bolt lift either. If you are lucky, you will have both the 'click' and the heavy bolt feel at the same time, but not always!

Use caution in your loading. Remember, the bolt thrust goes up to the square of the area. You have 91% more area in the fifty case head than with the 378 Weatherby. The .50 BMG case also has a bit more taper which works to "wedge" the case against the bolt face. When the bolt unlocks the case, it should fall out of the chamber. Even under nominal pressures, the bolt still has a great amount of thrust on it when fired and the case head "jams" against the bolt.

Another place to be leery is when changing any component even one of the same weight such as the 750 TCCI for the 750 gr. Barnes. While these bullets weight the same, THE BEARING SURFACE IS MUCH DIFFERENT and will lead to greater pressures in one than the other. ALWAYS BACK OFF AT LEAST 10% IN POWDER CHARGE WHEN CHANGING ANY COMPONENT!! It's cheaper to use a little more time than have to crate your \$3000 toy up and ship it off to get it fixed - quicker too!!

Loading the 50 is no different than any other cartridge with these few exceptions. Be cautious - it's a lot easier on equipment and the loader both.

Ken Johnson has had a couple of brakes hit with exiting bullets or bullet fragments just off center of the exit hole. These hits haven't hung up the bullet; the bullets have hit down range, although, quite a ways off of the intended point of aim. Others have had the inverted cones in their brakes abraded badly or the exit holes in brakes without cones eroded badly.

The only two things that Ken, Eric and I have been able to come up with are the great amount of powder we burn in these fifties promotes brake erosion, and the other thing is a problem with military ball bullets jacketed with a solid steel core and a lead cap on the rear. We have evidence to believe that the lead plug in the rear of the ball bullet is leaking powder gases which loosens the core from the jacket enough to unbalance the bullet when it exits the bore.³³ In addition, the lead plug can blow loose from the bullet at the muzzle. Eric Williams has found lead impact craters inside his brake on his 50 improved. He had been using some surplus US ball bullets that had some damage to the lead base plug for some fireforming chores. Eric recommends that you examine each ball bullet for lead plug looseness or damage. If poor quality bullets are found, save these for a gun without a muzzle brake.

Lynn McMurdo had made the mention of finding pickups (fired bullets) he shot into snow banks in Wyoming with rear portion of the boattail swelled and the cores loose. While this doesn't happen all the time, it seems to be happening often enough in spurts to warrant some investigation. We need more documentation on these problems. If you have any, please write the editor so we can put together the information.

This is a new sport, with many new people using and experimenting with different equipment. The infancy of the sport will bring many questions to light, and in the long run with further experimentation, many answers will be found.

One of the primary reasons there is so little specific loading data for the fifties is the tremendous variation in components. There are the different compositions of bullets and their great variation in diameters along with the variation even in the same type of powders such as various lots of 5010 powder. Your V.H.P. editor is trying his best to come up with a way we can get an adequate guideline in place for reloading data but it is going to be a challenge, to say the least, until components start to become more standardized. The longer we reload and the more people we have shooting the fifties, the sooner this will come about. We have seen

greater change since the formation of the FCSA than in the previous 20 years simply because the demand is becoming greater. Your participation is showing great results.

One last shot remains. I have heard more than several times of the problems people have with the Dominican ammunition. While loaded ammo is sometimes hard to come by, and good ammo costs more than we'd like to pay, **YOU GENERALLY GET WHAT YOU PAY FOR**. The Dominican ammo is likely to cost you more than you really want to pay for it in busted equipment. There is substantial variation in pressures in this ammo.

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The previous article bears some careful reading and should be followed as a set of rules when developing a special load or when using military pulled bullets for new loads.

We have some pretty good established rules established by dedicated people in the FCSA. Through the research and efforts (out of the individuals' pockets), some very good ground rules and warnings were established. This section is NOT designed to teach a person how to reload that has not done it before. It is intended to give an established reloader the information that he needs to reload the .50 caliber cartridge to support his shooting discipline. In this chapter we have taken a look at the various military cartridges and their bullets, the high grade civilian developed match bullets, and the safeties and warning signs of developing a load. Now we are going to take a look at the other components necessary to develop a good load. A good bullet is a key component of a high precision load, but without good powder, a primer, a case and good reloading equipment, the bullet can't solve the accuracy problem alone.

The following information is from a test and printed in an article by Eric Williams of the FCSA. The article was presented in *VHP* magazine, 1993 #1 issue. Individuals who have reloaded for precision know the value of a primer in gaining the utmost in accuracy of a rifle/load combination. As has been the case in many of these articles, I had attempted to extract pertinent points of information, but realized that in doing so I was leaving out very interesting points every time. With that in mind, the following article is reprinted in full as it appeared in the *VHP* magazine.

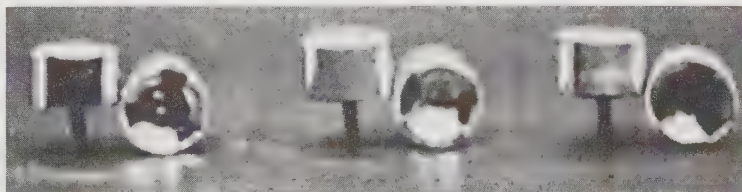
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THE PRIMERS

by Eric Williams

Imagine a fifty caliber from a much earlier era. It's a muzzleloader and the year is circa 1750. The first written publication by Roger Bacon describing gunpowder appeared better than 500 years earlier; yet, an efficient method of igniting that long known gunpowder is still not available. Yes, there have been advancements through the match- lock, wheellock to the flintlock, but the chemistry used to make primers, as we know them today, will not be known for another 50 years.

Moving ahead to 1800, Edward Howard published a paper on the preparation and properties of mercury fulminate thus, a major breakthrough in the development of modern firearms was made with this discovery of the first widely used priming compound. This breakthrough in organic chemistry set the stage for the



RWS, CCI, and IMI primers, left to right. Look closely to see that the anvils are visible below the cups of the CCI and IMI but not the RWS. The RWS cup face is rounded and the others are flat.

development of the modern cartridge as we know it today. The first fulminate percussion caps appeared around 1822, and some type of fulminate priming composition was used for the next 100 years. Because of the corrosivity, expense, relatively poor shelf life, and toxicity of mercury fulminate, other priming mixtures came into play after 1930.

Modern priming mixtures represent the most critical aspect of cartridge manufacturing. A considerable amount of research has been done with priming compositions. Priming compositions of today can consist of the following materials: an initiator, sensitizer, oxidizer, fuel, frictionator, and binder. To succinctly describe the components, the Initiator is the primary percussion explosive in the mixture. The almost universal initiator is lead styphnate. This is the replacement compound for mercury fulminate, and it makes up about 40% of the priming mixture. A sensitizer of tetracene is sparingly used (4%) to make the initiator a more sensitive percussion explosive.

A fuel and its oxidizer makes up the bulk (50%) of the remainder. Since the initiator burns too rapidly to reliably ignite the powder, a slower burning fuel and its companion oxidizer are used to extend the length of the primer burn. The fuel is usually antimony sulfide, commonly used in match heads, and the oxidizer is often barium nitrate. For fifty caliber primers, aluminum powder makes up part of the fuel, since it provides for better ignition in larger cases.

A frictionator (ground glass) is generally needed in rimfire priming compositions since primer anvils cannot be used in rimfire cartridges to activate the primer. Upon firing pin contact, the explosive crystals are fractured either against an anvil or by a frictionator. The energy of this crystal fracture initiates the explosive priming burn.

The final chemical component, the binder, simply holds the priming mixture together; otherwise, it would be a divided powder. Aside from the chemicals, a Boxer primer consists of a cup and an anvil. The cup and anvil are made from cartridge brass, and are sometimes nickel plated mostly for cosmetic and identification purposes.

I'll draw the line here on the background information and get to the meat of this article - fifty caliber primers. Currently, there are only two primers readily available to fifty caliber reloaders: the RWS #8212 and the CCI #35. Some time back I was able to get some MI primers from Marty Liggins at Accurate Arms Co.

With the IMI, RWS and CCI primers in hand, I set out to do some comparative testing. Rounds were loaded from new IMI brass using Speer/IMI 647 grain ball projectiles with both Ball (T5070) and extruded (AA5010) powder. All rounds were fired from a stock McMillan M87 rifle with its 29 inch barrel. Five rounds of each combination of powder and primer were loaded for a total of 30 rounds. The charge weight in all loads was 235 grain. This charge weight gave very similar ballistics to military ball loadings, but is only recommended with these particular lots of powder.

Over the course of firing 30 rounds, a fifty caliber light-barreled rifle can get quite hot and fouled. In order to average out these effects, the six different loads were fired in a sequence of load 1, load 2, load 3,...load 6, load 1, load 2,...etc. until all 30 rounds were fired. Collected data included; group size, case head expansion, velocity, and velocity extreme spread.

The most important point to be made about the data is with regards to the differences in velocity and pressure. The IMI and CCI primers are certainly hotter than the RWS. This fact was made obvious to me the first time I used the CCI primers. A simple substitution of the RWS primer with the CCI brand in a load that I was quite familiar with resulted in some surprisingly higher than nominal pressures. Since that time, I've found it to be necessary to reduce powder charges by about 5% when substituting RWS primers with either of the other two. We can look at the IMI and CCI primers as magnum primers relative to the RWS. I

spoke to Dave Cumberland, the Old Western Scrounger and exclusive importer of the RWS primers, about the differences. Dave claims the RWS primer contains the same amount of priming composition as the others, but it produces a "softer" and longer duration flame which results in less shattering of the propellant grains.

Primer Test Results

Primer	IMI		CCI #35		RWS #8212	
Powder	AA5010	T5070	AA5010	T5070	AA5010	T5070
Group Size (in.-100 yd)	1.71	1.07	1.78	1.71	2.17	1.43
Head Expansion (in.)	.00046	.00028	.00050	.00034	.00024	.00022
Velocity (fps)	2682	2713	2694	2728	2628	2687
Extreme Spread (fps)	30	22	62	29	39	91

Notes: All rounds were fired from a stock McMillan M87 at 75°F. Load: 647 grain Speer/IMI bullet; powder charge - 235 grains. Velocities measured at ten feet ahead of muzzle with an Oehler M35P. Results the average of five shots per load.

Although the above data doesn't show the RWS primer to have any accuracy advantage, my experience in match load development has always resulted in finding the RWS primer to produce the best groups in three different guns of mine. I've noticed the CCI primers have been indicated in a number of loads published in recent match reports; therefore, my findings may not hold true in every case. I will strongly recommend that you try both the CCI and RWS primer in any of your load development you'll see a difference between the two.

You may also notice the superiority of T5070 powder to the AA5010. The T5070 gives higher velocities, and smaller groups at lower pressures than AA5010. Some may rightfully argue that one sample doesn't produce statistically reliable data, but I have found over the years that T5070 is one of the best matched powders for the .50 BMG case.

There are also physical differences between the three brands of primers. Both the IMI and CCI primers have brass cups, and the RWS is nickel plated. The RWS and IMI primers share a three legged anvil with the CCI possessing a two legged anvil. These differences make for easy identification between the three brands. It also indicates that CCI doesn't resell IMI primers like they do with the IMI bullets.

The RWS primers are different in one other way. With both the CCI and IMI, primer activation occurs in the same manner as with common rifle primers. Before the primer is seated the anvil protrudes slightly above the lip of the primer cup. Upon seating the anvil is pushed against the priming mixture by the bottom of the primer pocket. An unseated RWS primer already has the anvil flush with the lip of the primer cup, but the face of the primer is convex. Upon seating the RWS primer, the face is flattened, which pushes the priming mixture against the anvil. The same results are achieved with both anvil primers but in a different way. Although the RWS activation system is unconventional, I cannot find any problems with doing it that way.

The fifty caliber primer is .316" in diameter compared with a large rifle primer of .211". Maybe we should call it the jumbo rifle size. Their price is certainly of the jumbo size at 16 cents each. In proportion to smaller calibers this is the most expensive component the fifty reloader must purchase.

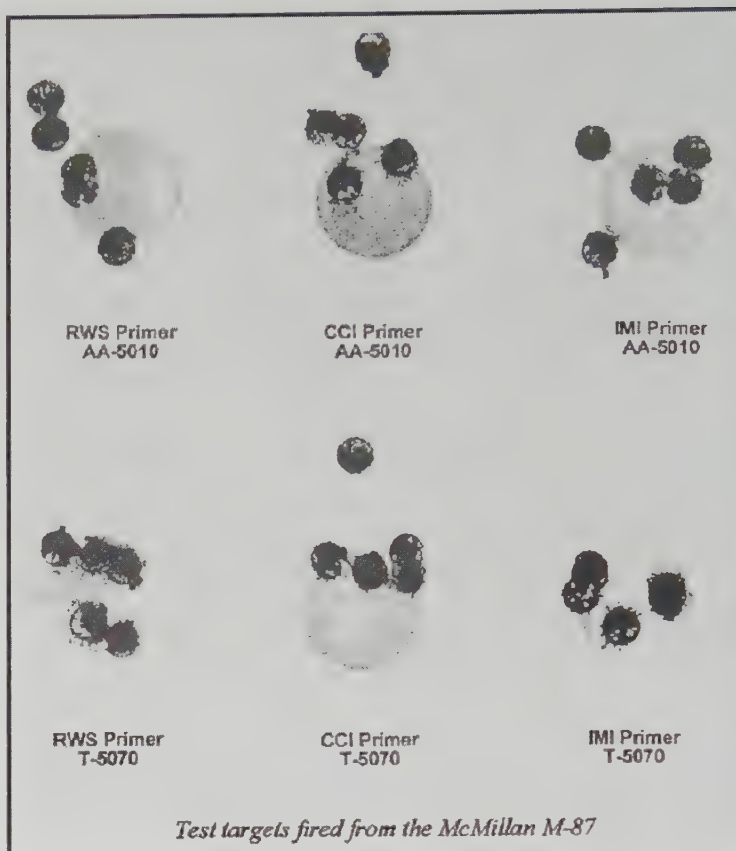
With the proper priming tools consistent primer seating can be achieved by either type of primer. I've

been using a Lee hand press topped with a C-H fifty caliber priming die. This is the same top priming method used in the typical hand held tools for smaller calibers. I get a good "feel" using the Lee hand press as a priming tool.

Other tools which are important to the match shooter are the primer pocket uniforming tools. I use both the flash hole deburring tool and the pocket uniforming tool made by K & M Services. Military brass (the only kind we have) doesn't have near the dimensional consistency of Sako PPC match brass, but with the proper tools steps can be taken to make match quality brass out of military brass. Consistent propellant ignition cannot be achieved without uniform primer pockets.⁹³⁴

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This section covers the different .50 caliber reloading powders that are in use. For those who are familiar with conventional reloading materials, you will notice that there aren't nearly as many powders available for .50 caliber reloading as there are for 7.62mm for example. The following tests are somewhat dated (1994) but the data still applies. There are two tests, one by a VHP staff member (Eric Williams) and another by the Oehler Corporation by Jack Hollinger.



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POWDERS—IMR 5101

A Test by Eric Williams

Powder—the heart of the cartridge. It results in the conversion of chemical potential energy into mechanical and heat energy. It's an amazing substance when one considers the combination of high energy density, long-term stability, and its ability to release energy rapidly on demand. Being a chemist, I can appreciate these chemical qualities for which many just take for granted.

If you're a handloader, there are probably other aspects of powder which you may take for granted. One attribute of powder which we generally trust is the burning rate of the multitude of available powders. If we buy a can of IMR 4350, for example, it will perform almost identically to any other can of IMR 4350. This is because commercial powders for reloaders are canister grade powders. To be a canister grade powder it must meet a specific criterion for burning rate. Now, for a powder manufacturer it's not all that easy to produce powder from batch to batch which meets the requirements for a canister grade powder. Rarely is a batch identical to the previous batch or the next batch. This is because the formulation of a

powder is a science where not every detail is understood. There are many variables which cannot be finely controlled in the formulating process.

Let's digress for a minute to the various components which go into a powder formulation. The predominate component of smokeless gunpowder is nitrocellulose (the upper border of the following two pages is a depiction of the chemical structure of nitrocellulose - just another reminder that a chemist wrote this article). It doesn't matter if we're talking about .22 rimfire powder or 16" naval cannon powder, it's nitrocellulose that provides the predominance of energy to the powder. Energies of powders can be boosted somewhat with the addition of nitroglycerin.

There can also be stabilizers, deterrents, plasticizers, and lubricants added to the final product. The key to the burning rate of the powder is how all the components are formulated, and the physical dimension of the powder grain. The components are not just mixed uniformly together, but are applied at very specific times and in very specific ways. It all boils down to the fact that its next to impossible to get every detail the same every time.

Since variations occur from batch to batch, manufacturers store powder in countless lots. Only very few of these lots meet the requirements to be a canister grade powder. A manufacturer also has the option to blend powders of different lots to arrive at a specific burning rate. Even with blending there are still many lots remaining that vary considerably from the nominal canister burning rate. These non-canister lots are sold to major ammunition manufacturers use for ammunition loading. To use these various lots the ammunition manufacturer will adjust the charge of powder in the load until the desired ballistics and pressures are obtained. Tom Owsley of River Valley Ordnance has pulled many rounds of WCC .50 caliber tracer, and has found charge weights of B4R 5010 which vary from 190 to 230 grains. This gives you an indication of powder lot-to-lot variations that can be expected.

The essential message of this article is that most of the powders we are using for handloading the .50 BMG are non-canister grade powders. Simply put, not all 5010's, 860's, and 870's are the same. Most major powder distributors will require that their surplus powders must meet burning rate specifications, but these specifications can vary among distributors. I spoke to Tom Shepherd of Hodgdon about their powder specifications, and Tom said that all powders except 5010 must meet specifications. This means that 5010 bought from Hodgdon now may be quite different from that bought in the past or future. Accurate 5010 is checked for burning rate by firing in a 7MM Magnum. At the lower operating pressures of 5010 in a 7MM Magnum, one will not see as significant of a variation as would be seen in a .50 BMG at full working pressure. This means that Accurate 5010 can be expected to have variation in burning rate from lot to lot. The 5010 you buy from Hodgdon may also be quite different from the 5010 you buy from Accurate, and later in this article you'll find that statement to be very true.

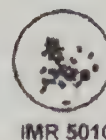
For this article, I've done some studies on IMR 5010 powder. IMR 5010 is an extruded single perforated grain powder, and is still commonly used for loading .50 caliber tracer rounds. Since extruded powders have higher flame temperatures than Ball powders, resulting from the use of more



IMR 3031



T-570



IMR 5010



M-1 Cannon



M-6 Cannon

Extruded powders can vary over a wide range of grain sizes.

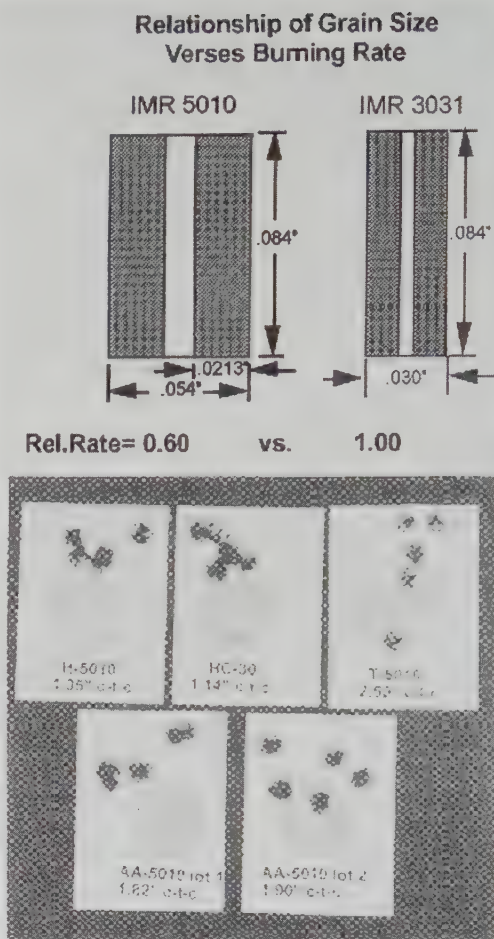
deterrent on the Ball powder grain, extruded powders ignite tracer mixtures more reliably. The extruded single perforated construction is the same for all the powders in the IMR series. The major difference between powders in the IMR series is the size of the powder grain with the larger grains producing the slower burning powders. On a relative burning rate scale with IMR 3031 having a burning rate of 1.00, IMR 5010's burning rate is 0.60.

The single perforation through the central axis of the grain is also important in determining the rate and characteristics of the burn. Without the perforation the powder would burn half as fast, and in a digressive instead of a progressive manner. The distance between the outer surface of the grain and the perforation controls the burning rate. In cannon powders large grains with multiple perforations are typically used. Here, the distance between the perforations is the controlling factor in burning rate with the multiple perforations resulting in a very progressive burning powder.

With the background information aside let's look at the results of this powder test. I had four different lots of 5010, two from Accurate, one from Hodgdon, and one from Thunderbird. I also had an extruded powder (HC-30) from Hercules which is distributed by River Valley Ordnance. HC-30 is dimensionally identical to 5010; therefore, I thought it would be a good addition to the test. For a testing load I chose what I thought would be a nominal load which I had pruned from a section on .50 BMG ammunition from *Cartridges Of The World* Vol. 6. This publication listed a load of 235 grains of IMR 5010 for an M33 Ball loading. Little did I realize that I was falling into the same trap that I'm trying to warn you about since some of those loads turned out to be very hot.

The five powders were loaded into new IMI cases over a CCI # 35 primer behind an IMI/Speer 647 grain ball projectile. Five rounds for each lot of powder equaled a total of twenty-five rounds for the test. The test was done with a stock McMillan M87 rifle at an ambient temperature of 85 deg. F. For this test, the order in which the rounds were fired was important to getting good data. Most know how hot a 0.50 BMG barrel can get when firing a string of 25 rounds. I also had to be aware of the effects of the build up of fouling on the data. To negate the effects of barrel heat and fouling the various lots of powder were fired in sequence going through all the lots every five rounds. This way the effects of heating and fouling would be averaged out over the various lots. Five separate targets placed at 100 yards were also used to collect comparative precision data. Velocity data was recorded with an Oehler M35P chronograph placed ten feet in front of the muzzle. No measurements of pressure were taken other than cartridge extraction and primer appearance.

Variations in the burning rate among these lots of IMR 5010 were clearly evident from the tests, shown in the table on the next page. From the slowest lot to the fastest lot there was



Results from a McMillan M87 with IMI bullets in various lots of 5010.

a difference of 190 ft./sec. in the measured muzzle velocity averages. Remember both the fast and slow lots were all sold as 5010 powder. The difference between these lots is greater than one will find between canister grades of B4R 4350 and B4R 4831. More important, the pressures ranged from nominal for the slower lots to those of proof loads for the fast lots. No primers were blown, but a cleaning rod was needed to extract some of the more heavily exercised cases. The two lots of AA-5010 turned out to be quite similar, although Accurate obtained the powder from different sources at different times. Both T-5010 and H- 5010 were practically identical to each other, but much faster than AA-5010. The HC-30 exhibited an average velocity very similar to AA-5010, but it resulted in a large extreme spread of velocities. Although the velocity spread was much greater than the 5010 lots, HC-30 gave the best 100 yard group at 1.14". Statistically, with only one sample, I don't think the accuracy data is of much value, but it does point out that velocity extreme spread does not correlate with accuracy.

The important point I am trying to make with this and other articles on ammunition variation, is that one needs to proceed cautiously when loading .50 caliber ammunition. With more variation than most other rounds in case dimensions, barrel dimensions, bullet compositions, primer brisance, and powders, one can more easily get dangerous pressures without expecting them. Keep in mind, with the fifty you're dealing with four times the powder than with your .30-06 which means any accident has the potential to be several times more catastrophic. If you are working with full loads drop back the charge by 10 to 20 grains when you open a new lot of powder. Another good piece of advice is if you find a powder you like, buy a large quantity of it since you may not be able to find it again when you run out."

IMR 5010 FIRING TEST RESULTS

Powder	Average Velocity	Velocity Spread	100 Yard Group	# Rounds	Comments
AA-5010 (Lot #1)	2740	50	1.82	5	
AA-5010 (Lot #2)	2703	26	1.90	5	
H-5010	2869	39	1.35	5	Reduce by 15-20 gr.
T-5010	2893	45	2.50	5	Reduce by 15-20 gr.
HC-30	2718	157	1.14	5	
PMC					
Factory Load	2721	83	2.27	5	Military Ball Load for Comparison

Conditions: .50 Cal. BMG fired in a McMillan M87 stock rifle (29" barrel) at 85 Deg. F. Bullet = 647 gr. IMI/Speer. Charge = 235 grains of powder, Primer = CCI #35. Case = PMC

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Reloaders and shooters for a long time have stated that a gun shoots well or fails to shoot based partly on the vibrations set up the the firing of the cartridge. Consistency in powders, powder loads, primers and bullet setup all have an impact on the vibrations as well as other factors. Oehler has a ballistic computer that can help prove this theory. The following article by Jack Hollinger presents this system and an analysis of its performance and what he was able to learn about the above stated theory.

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OEHLER M43 TESTS OF POWDERS IN THE .50 BMG

by Jack Hollinger

Why does an accurate rifle shoot small groups with some ammunition but not with all, equally well prepared loads? We know uniformity in all aspects of loading and shooting is crucial, but why does a particular combination of case, primer, powder, charge weight, bullet, seating depth, etc. group better than cartridges using the same components but varying the powder type and/or charge weight? Theorists and experimenters say barrel vibration is affected by changes in ammunition and influences group size. In any event, it seems safe to assume that the greater degree of sameness we can build into our handloads, the smaller groups we can produce.

To that end, handloaders sort cases, ream/turn neckwalls, uniform flashholes and primer pockets, weigh primers and bullets ad infinitum looking for the magic combination that will produce the perfect one-hole group at all ranges. We accumulate measuring devices to assist us in our efforts to produce cloned ammunition and have gained some control over many of the variables in the accuracy equation

Many of my shooting friends detest the load development process. Give them an accurate rifle and loading data proven to produce good groups and they're happy to spend their available time improving their shooting skills. Amen!

Fortunately, for those of us who derive as much satisfaction from tinkering as we do from shooting, Oehler Research has developed an affordable (all things are relative) measuring device which opens new doors to handloaders. The Model 43 Personal Ballistics Laboratory provides information about muzzle velocities, remaining velocities down range, computes ballistic coefficients, time of flight, trajectories, drift information, bullet energy and, used in conjunction with a lap-top computer with a strain gauge mounted on the rifle barrel, show pressure curves of individual shots as they are fired. The system tells us, in relative terms, what the peak pressure was for each shot, how the area under the pressure curve compares from shot-to-shot and the time in microseconds from the 25% point to the 75% point on the pressure curve; thus, providing insight into the relative burning rate of the powders we use.

The description of the Model 43 system's capabilities is



Close-up showing the attachment of the strain gauge to the rifle barrel.

not complete. The system does more but for purposes of this article I'm going to concentrate on its potential use as a way of finding the optimum powder for a given rifle/cartridge/bullet combination. Specifically, my objective is to begin to accumulate data about the performance of propellants in my fifty caliber rifle. Clearly this information will be specific to my rifle and I caution anyone reading it not to assume any of these loads will be safe in any other rifle. The information herein is intended to show these combinations performed in a particular rifle under specific conditions. In developing loads for your rifle use caution and common sense.

I started this experiment with the bias that the closer the pressure curves of individual shots paralleled one-another and the more precisely barrel times matched, the more uniformly the barrel would vibrate, consequently, producing tighter groups. This bias begs the question of how accurately I could read changing atmospheric conditions, hold, squeeze the trigger, etc. Many of the variables are uncontrollable. Since my objectives in these tests relate to propellant performance, I can live with uncertainties about group size.

In the future, I'll use the same process with other rifles. The fifty caliber was picked to begin with because I have less information about powders for it than for the others.

Components used were unfired IMI TZZ 89 cases sorted by weight (797.5 - 800 grains) with primer pockets uniformed to a depth of .223, CCI #35 primers selected to measure .223 and seated as accurately as possible to a uniform depth, 750 grain McMurdo flatbase spitzers with Lynn's drawn jackets seated to an overall length of 5.27" to touch the lands. Powder charges were individually weighed at 226 grains each of T5070, H5010, WC872, WC860 and T870. I have been unable to obtain samples of the VihtaVouri powders but Ross Duckworth assures me he will provide them when available.

The rifle built on an American Arms & Ordnance receiver with a K & P 33.1" fluted, stainless, 12" twist barrel. Metal work including a three-lever trigger and muzzle brake was done by Charles Poff. The barrel is Melonited and when tests began had fired 397 rounds, 236 of which were Barnes brass bullets.

Because the focus of the tests was powder performance, the load used was not selected for accuracy. It was chosen because previous loading has indicated it to be a moderate load with all the powders involved. Here-to-fore my best accuracy has been obtained with T5070 and 800 - 850 grain bullets. The best group fired during the tests measured 3.05". All groups were fired at 303 yards off sand bags. Group sizes ranged from the above smallest to 6.4" with McMurdo bullets. The 3-shot control group with Lake City 86 ball was 9.85".

The printouts are reasonably self-explanatory. Under the heading "shot data" the column headings "Peak", "Area" and "Rise" refer to estimated relative maximum pressure, the area under the pressure curve from estimated ignition to bullet exit, and the time in microseconds from the 25% point to the 75% point on the curve, respectively. As you can see, T870 produced the most uniform pressure curves in this series with H5010 the runner-up.

Each of the other powders produced one or more curves which deviated significantly from the norm. My hunch is these are examples of the much discussed phenomenon resulting from reduced loads of slow burning powders. As you can see in the photograph illustrating relative volume of powders used. None of these loads approached 95-100% loading density. The capacity of these cases in grains of water averaged 273.18 filled to the base of a bullet seated as they were. The charge of 226 grains, therefore, represents 82.7% of capacity by weight.

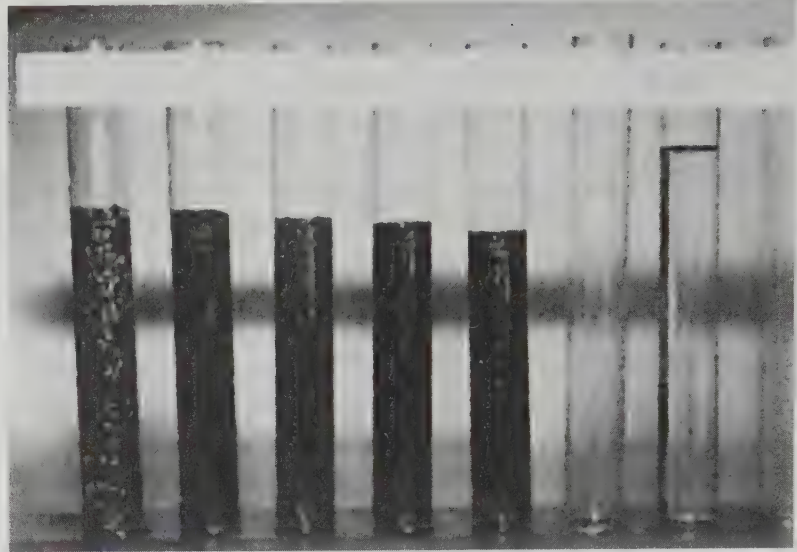
I've included a copy of a similar test run on my .340 Weatherby hunting rifle to illustrate pressure curves which are extremely uniform. Notice the vertical ticks near the end of each curve, which represent bullet exit, are in nearly the exact same position and the rise numbers 172, 172, and 174 indicate uniform barrel time. This rifle printed a group measuring 0.6" at 303 yards.

No attempt was made to correlate bullet impact with pressure curve/barrel time deviation. I will do so in later experiments. It seems reasonable to assume there should be some correlation.

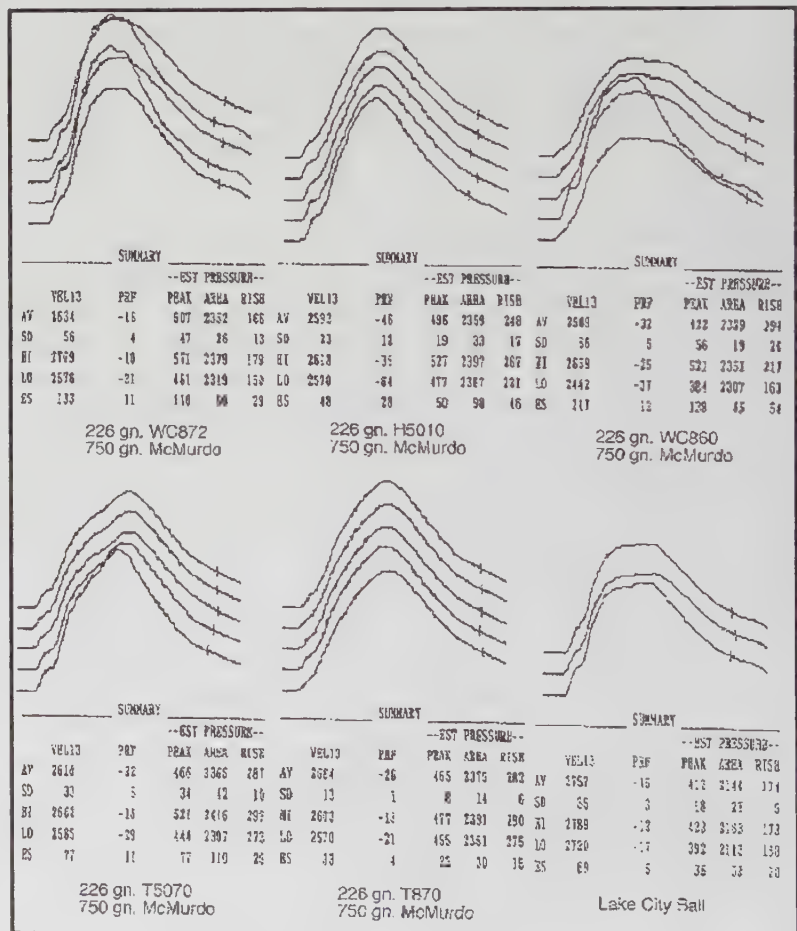
As expected, the powder showing the lowest peak pressure (WC860) registered the lowest velocity, but who can be sure what to make of the area and rise figures? Notice the similarity between the curves for the Lake City Ball and the WC860 load. This similarity is not surprising since US military Ball is known to be loaded with WC860. The other four powders are too close in burning speed to make a statistically significant call on their order of burning rates.

I'm convinced that the Oehler 43 system will reveal things about powder performance that would remain unknown to handloaders without it. It's fun to speculate about what would show up if similar experiments were conducted with the PPC calibers and the various propellants used in them. The next experiment, which will be made when weather permits, will involve the same components in the same cases with an increase in powder charge to determine what effect greater loading density has on powder performance.

The very limited results are not extensive enough to draw many conclusions from. In fact, they raise more questions than they answer. However, I do have data I didn't have before and I eventually will have a lot more."³⁶



This photo illustrates the relative bulk densities of powders in the test. Left to right, IMR 5010, T5070, T870, WC872, WC860, and case capacity in water.



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The next major component of reloading is the case itself. The search for quality .50 caliber brass has been going on for a long time. The military surplus brass is a large source of brass for loaders and there is also a civilian market for the non-military produced brass. Again we turn to information provided by Eric Williams for an examination of the available brass and what we look for in that brass. Then we will take a look at the benchrest shooting methods of preparation of the cases and what good that process does for precision.

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THE BRASS

By Eric Williams

The precision minded shooter scrutinizes the quality of their loading components. The most demanding quality is expected from bullets. Poor quality bullets will invariably take their toll on group sizes. After bullets, the other components (cases, powder and primers) arguably compete for importance in quality demanded. Regarding powder and primers, since we don't have any easy method to measure their quality they are selected on a trial and error basis and are used as is.

Cases are a different story. One can cull rejects and uniform some of the case's dimensions. Even though the shooter can take the quality control issue into their own hands, to some degree, only the best available brass is purchased for match competition. Purchasing the best available brass is important because attributes like case wall concentricity and brass hardness cannot be corrected. Another factor comes into play for the fifty caliber shooter, and that is with regard to availability. Currently, there is only one brand of fifty caliber brass available in new, unfired condition; that is IMI.

Fortunately, IMI brass is of good quality and it is highly sought after by the match shooting crowd. I've wondered just how good the quality of B41 brass is in comparison to brass of other manufacturers and other calibers. Toward this question, I've weighed 200 pieces of new IMI brass along with some PMC fifty caliber and some new Remington 8mm Mag. brass for comparison. Keep in mind, without measuring several items like concentricity, weight primer pocket uniformity, and hardness, one cannot get the full picture of the brass quality. I'm also not inferring that weight is the most important attribute for accuracy; its just the easiest to measure. We might assume that if high quality control is found in the weight then high control can be expected with the other attributes. Actually, I think the opposite may hold more truth; that is, if a large weight dispersion is found then quality control with the other attributes is suspect.

I've taken 200 new IMI cases, before any uniforming or neck sizing work was performed, and weighed them. The results are presented graphically in a histogram. This data doesn't tell us much without some comparison data. For comparison, I took 80 new 8mm Rem. Mag. cases and 40 once fired, deprimed PMC .50 BMG cases (all that I had on hand) and weighed them. The result show that the IMI brass, in terms of weight consistency, is no better and maybe not as good as the PMC and Remington brass. For weight the IMI, PMC, and Remington brass averaged 799.6, 832.2, and 254.7 grains, respectively. Standard weight deviations, in the same order, calculated out to be 4.78, 2.30, and 0.93 grains. For comparative purposes I've divided the standard deviation by the average weight to give the percent of deviation per unit weight. This is the only way we can fairly compare the much lighter 8mm

brass with the .50 caliber brass. These percentage numbers are 0.60%, 0.28%, and 0.36%, respectively, for the IMI, PMC, and Remington brass. Now, I must admit that the standard deviation numbers are effected by the sample size, and the PMC and Remington numbers would likely be higher if 200 of those cases were measured. I do believe that quality control on brass weight is nothing exceptional for the IMI brass.

I believe that the primer pockets on the IMI brass are highly uniform, even though I don't have measurements to support this claim. I have yet to find a burr on the inside of any flash holes with this brass. Also, in using a pocket uniformer with the IMI brass, I've witnessed a high degree of dimensional uniformity. This is not what I've found with much of the US brass such as Lake City (LC). With less uniform brass you never know just how much cutting the primer pocket uniformer tool will do from case to case. With the IMI brass it's always the same.

Even though I've made an issue with the weight uniformity of brass, I believe that primer pocket uniformity is much more important. All the events which take place from the moment of the firing pin strike to the bullets exit must take place in a repeatable manner for high levels of precision to occur. Uniform primer ignition is necessary in this chain of events, and uniform primer pockets are required for uniform primer ignition.

Another attribute of brass that I believe we need to pay close attention is case wall concentricity. A lot of this belief stems from reading some of Merrill Marties articles in Precision Shooting. To briefly sum up the findings of Merrill's experiments, one has to consider what happens to a case with an inconcentric case wall upon firing. The thinner side of the case will give first under pressure. As a result, on firing the case will stretch into a "banana like" shape. This non-uniform stretch, in turn, places an initial off-center force against the bolt face. If this force is not identical from shot to shot then the dynamics of the barrel will also not be identical. Non-uniform barrel dynamics simply translates into shot to shot dispersion.

Something can be done to correct for this problem. First, we must recognize that we cannot expect to get perfectly uniform brass in terms of case wall concentricity. What we can do is measure the case wall to find the thin side. When it is located the thin side can be marked by filing a small notch in the rim at that point. Of course, any cases that are found to be highly out of concentricity should be culled. Once the thin side (or thick side, as long as one is consistent) is located it can be indexed into the chamber the same way for each shot. This way, the off-center force of the case head against the bolt face will have approximately the same effect on the barrel dynamics for each shot.

One problem I've encountered in trying to do this is with finding a good tool to measure the wall concentricity for fifty caliber cases. The new RCBS CaseMaster tool is just not robust enough for the fifty caliber case. The small diameter feeler rod used on the CaseMaster flexes too much to allow for repeatable measurements. Skip has also reported that NECO's concentricity tool and Verne Juenke's electronic measuring device are not satisfactory for doing this measurement. Only recently have I learned about NECO's new tool designed specifically for the .50 BMG cartridge. This tool is a scaled up version of their tool designed for all the smaller cartridges (mentioned above). It is somewhat expensive at \$167.50 but you usually get what you pay for from NECO. I'll be getting one of these shortly and will report in the next issue on its function.

Getting back to the weight measurements, I wanted to see if I could measure any shooting effects as a result of sorting brass by weight. Since I wasn't able to index the cases by concentricity, I didn't feel that any accuracy differences found could be attributed to the weight sorting alone. Instead, I felt that one might see greater spreads in velocities for the unsorted brass than the sorted brass. Since the chamber volume is constant and assuming that

all of the pieces of brass are made of identical density brass, lighter brass will result in more powder burning space than heavier brass. If the difference is enough then the heavier brass should result in higher chamber pressures and, in turn, higher velocities.

Ten pieces of brass were selected that weighed between 799 and 800 grains. In addition, five of the lightest cases found were marked as well as five of the heaviest. These light and heavy cases were combined, in effect to stack the deck towards non-uniformity. The tests were done in my .50 BMG Improved rifle; therefore, the cases were neck turned and fireformed first. Identical loads of 285 grains of T570 behind a TCCI 750 grain bullet were used for all twenty rounds. The uniformly sorted cases resulted in an average velocity of 2792 ft/sec and an extreme spread of 50 ft/sec in velocity. The mixed light and heavy cases gave an average velocity of 2797 ft/sec (statistically insignificant difference) and an extreme spread of 68 ft/sec in velocity.

Before you jump to conclusions and think that the 18 ft/sec more spread in the mixed cases was due to the weight non-uniformity, I need to add some more data. The average velocity from the five lighter cases was 2799 ft/sec while the five heavier cases averaged 2795 ft/sec. This difference is statistically insignificant. Even if the difference was significant, these results are the opposite of that predicted from the chamber volume argument I presented earlier. I was also careful to shoot the test by alternating between both lots of brass (within the mixed lot, light and heavy cases were also alternated) so that barrel heating and fouling would average out over the whole test.

By the way, I did measure the ten shot group sizes from these two lots of brass, and they were statistically the same.

The bottom line for me is that I will not continue to waste time by sorting brass by weight when I believe that other attributes of brass dimensions are more important. Regarding measuring case wall concentricity, I will pursue this avenue when I have the appropriate tool to do the measurement. I will also run experiments to see if significant results can be found and will report on them in due time.

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This is an article by a FCSA competitor that ran an informal test to determine if all the careful case prep that is done by a benchrest shooter is actually worth the time and effort. Why is this valuable information for a sniper or military HTI shooter? It gives a basis for determining what can be gained by all the careful case prep that is normally NOT done by military shooters. Precision reloading may be done with special authority. But going into full blown case modifications generally lowers the possibility of getting approval for such operations. At SOTIC at Fort Bragg, we were given the authority to reload ammunition for precision and as in battlefield recovery. This involved hand reloading tools such as the Lee reloader. Clearly this can't be done with the .50, but the precedent does exist for precision reloading in military units. The article follows:

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THE CASE FOR CASE PREPARATION

by Dan Zignego

The majority of shooters at the FCSA regional matches handload their ammunition. The reasons for handloading are numerous but the main reason match shooters reload is for accuracy. Accuracy is achieved by developing a load for a particular rifle. Part of this load development involves cartridge case preparation. The amount of case preparation that .50 BMG match shooters do tends to be sort of an all or almost nothing process. This separates the shooters into two groups which I will label the Benchresters and the Handloaders.

The Benchresters treat case prep much like their smaller bore counterparts. Cartridge cases are segregated by lot number, weight and / or capacity. They are then trimmed to a standard length and the case mouth deburred. The primer pockets are uniformed and the flash holes reamed. The outside caseneck is then turned with brass being removed around the entire neck to make it more concentric. These cases are fired in rifles whose chamber neck diameter is less than the standard .50 BMG dimensions. This is necessary to accommodate the thin neck brass which would be overworked if fired in a larger chamber. The tight chamber contributes to accuracy as well.

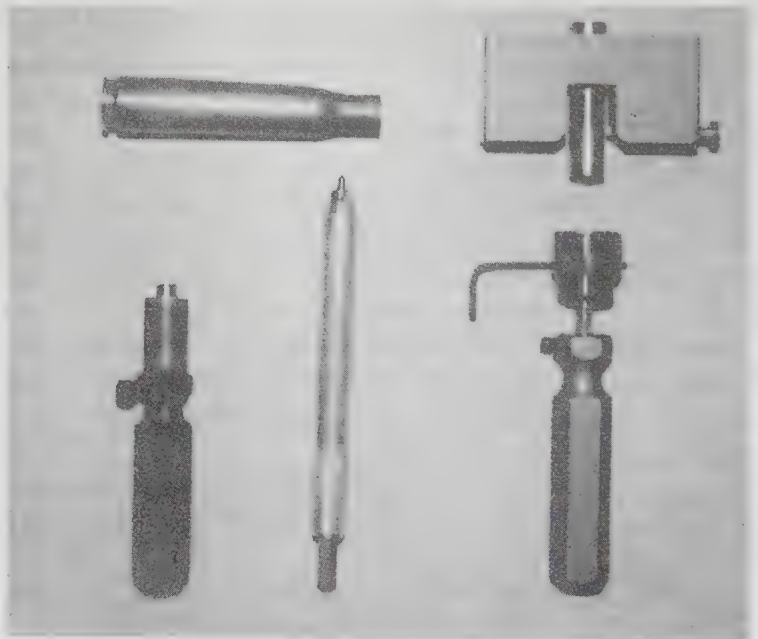
Most of the Handloader³⁷ group treats case prep in a more nonchalant manner, choosing instead to rely on our finely tuned shooting skills to win the gold. This group tends to segregate brass by headstamp, trim to length and debur the casemouth. The primer pocket crimp will also be removed if dealing with surplus brass.

I have watched and talked with a few of the Handloader group who also uniform primer pockets, ream the flash holes and turn the case necks just enough to remove the high spots. This type of case neck turning results only in a maximum of about 30% of the case neck area being cut down and allows for shooting in a standard chamber.

The extra steps the Benchresters and some of the Handloaders do take time and involve an additional investment in equipment of about \$150.00, is it worth it? Can one improve the accuracy by preparing the cartridge case in such a fashion and shooting it in a standard chamber rifle? To find out I developed the following test:

A) I would handload 5 groups of 5 rounds each with the case prep consisting of separating cases by headstamp, trimming to the same length, case mouth deburred and the primer crimp removed. The load would be one I know to be accurate at both 100 and 1000 yds. Each group would be fired and measured at 100 yds. The size of the groups would be determined by the distance between the two shots furthest apart measured on the center of each shot.

B) The same brass would then have the primer pockets uniformed, the flash holes reamed and the highspots turned off the casenecks as well as the initial steps described in A above. This brass would then be fire formed before the comparison rounds are loaded. This is necessary because the turning of the case necks causes a somewhat loose fit in the chamber neck area and will be detrimental to accuracy as I found out. After the brass was fireformed it was trimmed, deburred and the primer pockets were cleaned with the uniformer. The same load as shot before was then used for the comparison groups.



K&M Services case prep tools: (left to right) primer pocket uniformer and handle, flash hole reamer, case neck turner, and shell holder.

AMMUNITION

- The results of the original five shot groups were as follows: Group size (inches), 1.290, 1.340, 0.540, 0.955, 0.515; average, 0.930.
- The results of the marathon case prep. groups were as follows: Group size (inches), 0.876, 0.627, 1.040, 0.816, 0.998; average, 0.871.
- The rifle was cleaned before each set of 5 groups was fired.
- The barrel was allowed to cool between groups.
- Two fouling shots were fired before each set of the 5 groups.

K&M services neck turner, primer pocket uniformer and flash hole reamer were purchased and used by the author. These tools are of excellent quality and almost make the job fun. They are well worth their cost.

The amount of improvement gained from the "Benchrest" type case prep. job was a reduction in the average group size of .059" at 100 yds. I doubt if this is statistically significant when one considers the small size of the sample (25 rounds) but it does show some probability of improvement which is more than I expected. I know I will continue to use the K&M tools to prepare match brass because any gain in accuracy is what it's all about.³⁸

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For the military shooter a group reduction of .059" at 100 yards is insignificant. The real test of this method would be to do a probability of hit (PH) test using 100 rounds at 1,000 yards with each method. Use a 1 minute of angle circle on the target with an outer circle of 2 minutes of angle. The goal is how many shots go into the 2 minute arc, with a desired level of accuracy of 1 minute of angle. The 1,000 yard PH test would easily determine the difference between these two groups of loaders. Of course, the guns and marksmanship capabilities will be tested under 1,000 yard shooting.

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RELOADING DATA FOR THE .50 BMG *by Skip Talbot*

We publish loading and equipment information in match reports in the VHP but these are pretty slim areas of loading as we only use match type guns and loads that seem to work the best regardless of what we'd like to use. If you are running at the head of the pack in competition the one bullet and load that shot the smallest groups for us is what we will use, not what we happen to have on hand.

Many people have various powders, bullets, brass etc. that they have no idea of what amount and combination they can start with to get the ball rolling. There is little in the way of information out there and I am going to try and explain why there isn't more information available from the commercial areas of reloading.

One of the more frustrating areas of the fifties is the fact that there are so very many variables concerning the total picture as a whole. You have bores running from a tight .495 " instead of .500" to grooves that measure about .509 to .512" instead of .510", throats that measure from .510" to .515" in diameter and throats from a short.140" long to over.500" long. There are land to groove ratios (land & groove equal 100%) that vary from 20% land/ 80% groove to 50/50 land & groove.

Then you have twist rates ranging from a fast 1: 9" of Klause Horstkamp rifles to the 1:

24" twist that Ken Johnson of K&P was playing with. These are for 650 grain bullets, you may also have neck diameters varying from .554 to .562" in diameter. There are barrels that vary from a short 28" long to the 45" aircraft barrels. Throw in bullets that are conventionally made with gilding metal jackets and lead cores to solid bronze (TCCI) bullets that are full bearing surface flat based & boat tailed bullets to the CNC lathe turned 800 gr. Barnes LRS bullets that have a front driving band of .5017" and a rear band of .5105" that is about .180" long to the 750 Barnes & McMurdo bullets that have rear driving bands of .250" long. We also shoot the Zero Index Bieber designed 12LI4 Leadloy bore riding steel bullets in specially nitrided Chrome Molly barrels.

In standard rifles and pistols you don't have this variation. One of the good things that has come out of competition in the FCSA has been the standard dimensions for the Light Rifle class. This means that many builders have reamers that match these criteria and so we have guns being built that all have approx. the same chamber dimensions in them. This simplifies things greatly and will get better as time goes on.

Now we can compound the derivatives by adding RWS, IMI, and CCI #35 primers all of various brisance and temperatures, along with the approx. 5 to 10 different powders available and load them in the 7 or 8 different makes of brass available.

When trying to read pressure signs during a loading session, I recommend that you do your load development with neck sized cases only! The reason for this is that you will find the bolt binding and bright extractor marks on the back of the case faster than if you have a full length sized case that can expand to fill the chamber and thus takes up some of the pressure that can give you a false reading. Also you will find a smeared primer many times in a full length sized case and think "boy, pressures!!" Nope, you just have a bit more headspace and when the case ignites, it has been pushed forward by the firing pin, the neck expands, holds the case in the forward position initially and as the pressure climbs it extrudes the primer out of the primer pocket back against the bolt, Then the brass follows suit, but the primer can't go back into the primer pocket. It's held against the bolt by 30,000 + lbs of pressure so it smears it flat against the back of the cartridge case head.

I recommend reading pressure signs by either or both the following methods. Micrometer measure the neck sized case at the web. After firing a neck sized case and getting over 1-1/2 thousands of an inch of diameter growth, consider yourself to be about at max. pressure and drop your load about 3 grains from this point.

The way I work is after firing the neck sized case, when extracting the case, check for bolt lift. If it's excessive you're probably at the same point. To verify this, put the fired case back in the rifle and close the bolt on it **IF IT GOES DOWN HARDER THAN A GOOD FIRM FEEL YOU ARE AT MAX. WORKING PRESSURE, BACK OFF AT LEAST 3 GRAINS AND TRY LOADING THIS LOAD 3 TIMES AGAIN.**

I would highly recommend you load this same load in the same case 3 times and check the bolt feel each of the 3 times. If the bolt feel stays about the same for the 3 times, you have a good working pressure load. **IF THE BOLT STARTS GETTING HARDER TO CLOSE YOU ARE STILL TOO HOT!! DROP THE LOAD ABOUT 2 GRAINS MORE AND CONSIDER THIS YOUR TOP SAFE LOAD.**

Most rifles don't shoot well at the very top end of pressures. There are exceptions to all rules, but it is a lot easier on brass and actions if you don't crowd the envelope. It also leaves you some breathing room if you go to an area of higher pressures such as coming down to sea level from 7500 feet M.S.L., or going from 35' F and 15% humidity to 90'F and 80% humidity.

I am going to describe three rifles, calling them A, B, & C. They represent the tightest

tolerances and smallest practical chambers with the longest barrels and thus the highest pressures for a given loading, to the mean average dimensions. This should fit most custom built rifles, to the largest, sloppiest dimensions which should give the lowest chamber pressures for a given loading. I'll comment on the different loadings such as substituting a hotter primer with recommendations as to the drop in loading recommendations in such instances.

RIFLE "A": with a 36" barrel, .495" bore (std= .500"), 1:10", twist (std = 1:15"), 60:40 groove to land ratio (std= 70/ 30). Neck= .554" diameter (std. .562 dia.), throat=. 140" deep @ .511 diameter (std match specs).

RIFLE "B": with a 32" barrel, .500" bore, .510 groove, 1:15" twist, 70:30 groove to land ratio, .558" neck diameter, throat .140" deep @ .511 " diameter. (close to standard match grade chamber and specifications.)

RIFLE "C": 29" barrel, .500" bore, .510" groove, 1:15" twist 80/20 groove to land ratio,.562 neck diameter, throat .500" long @ .511" diameter.

While this seems a bit confusing, if you study the above in relation to the notes during the loading recommendations, you will see where longer barrels might mean lower powder charges, and milder primers will allow higher loading charges.

The primers used are listed from coolest to hottest and the powders from fastest relative burn rates to slowest.

PRIMERS:

RWS, Note: When seating RWS primers, they are a round cupped primer. Seat the primer to the bottom of the primer pocket and then exert enough pressure to flatten about 75% of the top of the cup. This arms the primer as this primers anvil is flush with the bottom of the cup and the round cap has to be flattened a bit to arm the primer. When you seat the IMI or CCI primer, the anvil extends down below the cup, when pressed into the bottom of the primer pocket this pushes the anvil upward, arming the primer.

IMI

CCI #35

POWDERS USED:

ThunderBird Cartridge Company 5020

Hodgdon H5010

ThunderBird Cartridge Company 5050

Hodgdon 50BMG

Vihtavouri OY (VV) 24 N 41

Accurate Arms Powder Company AA8700,

ThunderBird Cartridge company T-870, Also about the same as surplus 870.

ThunderBird Cartridge Company 5070

Vihtavouri OY (VV) 20 N 29

CARTRIDGE CASES USED:

All BMG cases are pretty close to the same capacity considering the large volume of space taken up internally and I don't believe case capacity in this instance is as critical to excessive pressure signs as other items such as primer burn rate or bullet engraving pressure.

BULLETS USED:

From lightest to heaviest with notes considering engraving pressure versus weight. Bullets not mollyed except where noted.

647 IMI Ball, M33 Ball.

700 gr. McMurdo flat base copper jacketed lead core.

700 gr. Zero Index steel, tangent ogive, bore riding 12LI4 leadloy, mollyed.

700 gr. Thunderbird Cartridge Co. Flat base, sold bronze, mollyed & unmollyed.

750 gr. APT secant ogive solid copper swaged, aluminum tip, mollyed.

750 gr. Thunderbird Cartridge Co. Solid brass full engraving boat tail, unmollyed & mollyed.

750 gr. Hornady new design (2.5" long) VLD copper jacket, lead core, aluminum tip), mollyed.

765 gr. AAA Ammo, Solid copper, bore rider, moneyed 750 gr. Barnes bore rider LRS solid brass, mollyed.

765 gr. McMurdo VLD bore riding sold brass, mollyed.

800 gr. Barnes LRS bore rider, solid brass, mollyed.

NOTE: If you do not have a .502" bore riding throat in your rifle in addition to the standard .511" throat you will have to seat the Barnes LRS bullets deeper in the case to get them into the rifle. This in turn decreases case capacity and can lead to higher pressures. Start at the lowest loading and look for bolt feel (excessive extraction power required to open bolt and extract round³⁹) with 2 grain incremental additions each loading. Accuracy probably will not be as good as can be had with the .502" throat addition. This throat addition will not hurt the performance of any other bullet as it only takes about .001" off a .005" deep land and a regular bullet will seat and engage normally.

*DENOTES VIHTAVOURI LOADING PAMPHLET DATED 1-98. This information was with a rifle with a 45" barrel, CCI primers, IMI Brass trimmed to 3.902" LOA and cartridge length overall of 5.413". NOTE: This cartridge is not supported by CIP or SAAMI. The Maximum Loads do not exceed 48,500 CUP. This would class as an "A" rifle because of barrel length and burning time. I BELIEVE ALL THESE LOADS ARE WITH UNMOLLYED bullets. (author).

* DENOTES BARNES RELOADING BOOK INFO. Uses CCI #35 primer and military brass in the loading information above.

** DENOTES TCCI DATA, Contributed by Eric Lufty of TCCI, Thunderbird Cartridge Co., Inc. furnishes the preceding (** marked) data as a guide to the individual handloader. These data were derived from closely controlled tests, performed in our (TCCI) ballistic facility.

Cartridge data was derived from a .50 Cal. M2 Heavy Machine Gun with a 45" stellite lined chrome bore with a .4965 " bore and .5090" groove equally spaced with a 1:15 twist & a land width approximately .065" and groove depth of approx. .006". The chamber wall had been vent drilled and reamed to .206" at a point 1.250" forward of the bolt face and a matching piston fitted for the pressure tests.

BORE CARE: TCCI recommends the use of J-B Cleaning compound. It should be liberally applied to 2 military .30 Cal. patches wrapped around a tight fitting wire brush. Vigorously pass back and forth through the bore until any fouling is removed. Clean from the breech and use a cleaning rod guide.

McMillan barrels use a shallower groove depth profile, which does not meet government specifications. With repeated firings, fouling will occur and progress to the point that accuracy

AMMUNITION

647 Grain IMI or M33 BALL BULLETS

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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AA8700	CCI#35	N/A	205 grains / 2610 fps	228 grains / 2930 fps
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This was in a 44" barrel which would represent an "A" rifle load. In "B" rifle you might be able to go up another 4 or 5 grains at maximum and in a "C" rifle another 3 grains but start at 205 gr. and work up with bolt feel & web expansion at 2 grains a time. In this same rifle using an RWS Primer you might be able to go up an additional 2 or three grains before reaching max. pressure in each class rifle.

*VV24N41	CCI#35	N/A	212 grains / 2654 fps	223.3 grains / 2848 fps
*VV20N29	CCI#35	N/A	237.2 grains / 2701 fps	251.5 grains / 2942 fps

700 Grain MCMURDO JACKETED SPITZER, BOAT TAIL, LEAD CORE

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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AA8700	CCI#35	N/A	210 grains / 2592 fps	220 grains / 2722 fps
AA8700	RWS	N/A	210 grains / 2657 fps	223 grains / ?

700 Grain ZERO INDEX STEEL BORE RIDERS

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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VV20N29	RWS	60 Deg +	242 grains / ?	256 grains / 2850 fps
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The rifle for this load is throated .502" diameter for additional .300" over .511" standard throat length. *This bullet and powder combination is very temperature sensitive. At temperatures under 60 deg. F the groups tend to string vertically, so you must keep the ammo warm when shooting this load combination.*
****THIS LOAD SHOULD ONLY BE USED IN NITRIDED CHROME MOLLY BARRELS OR RAPID BARREL WEAR WILL OCCUR.****

700 GR. THUNDERBIRD SPITZER FLAT BASE, Not Molly Coated

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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**T5020	CCI#35	70 Deg. F	240 grains / 3011 fps 48,900 CUP	246 grains / 3078 fps 52,500 CUP
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**T-870	CCI#35	70 Deg. F	230 grains / 2884 fps 45,300 CUP	240 grains / 2980 fps 48,900 CUP
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**T5070	CCI#35	70 Deg. F	238 grains / 2919 fps 45,400 CUP	250 grains / 3046 fps 51,200 CUP
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* 24N41	CCI#35	N/A	208 grains / 2611 fps	225.5 gr. / 2836 fps
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* 20N29	CCI#35	N/A	223.5 grains / 2634 fps	250 grains / 2894 fps
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The loadings of both 700 and 750 gr TCCI bullets would be a good example of an "A" gun getting in trouble with the maximum loading. I'd recommend you start at least 6 grains less for each STARTING load with a rifle exhibiting at least two of the "A" guns characteristics.

700 APT SOLID COPPER. ALUMINUM TIP, FLAT BASE, Full Engraving Bullets, Molly coated

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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VV24N41	RWS	N/A	228 grains / ?	240 grains / 2909 fps
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Recommended Working Load = 232 grains / 2750 fps ("B" Gun Design)

VV20N29	RWS	N/A	235 grains / ?	242 grains / 2794 fps
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Didn't get good grouping with 20N29 as ignition was erratic, bullet needs faster powder, N41 a better choice, may be same in other solid copper bullets.

750 GR. THUNDERBIRD CARTRIDGE CO. SOLID BRONZE, Full Engraving Boat Tail, Molly coated

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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AA8700	RWS	N/A	220 grains / 2484 fps	233 grains / 2680 fps
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**T5020	RWS	90 Deg. F	200 grains / 2582 fps	225 grains / 2882 fps
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Temperature for MAX load is 110 Deg. F, MAX CUP = 48,980

**T-870	RWS	90 Deg. F	220 grains / 2746 fps	230 grains / 2897 fps
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Temperature for MAX load is 110 Deg. F, MAX CUP = 50,280

**T-5070	RWS	90 Deg. F	225 grains / 2774 fps	235 grains / 2900 fps
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Temperature for MAX load is 110 Deg. F, MAX CUP = 49,320

*VV24N41	RWS	N/A	202 grains / 2743 fps	219 grains / 2828 fps
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LOAD DATA FOR TYPE "A" RIFLE.

*VV20N29	RWS	N/A	222 grains / 2521 fps	243 grains / 2773 fps
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LOAD DATA FOR TYPE "A" RIFLE.

PRIMER SENSITIVITY COMPARISON BETWEEN RWS and CCI #35

**T-5070	CCI #35	70 Deg. F	237 grains / 2894 fps	50,200 CUP
**T-5070	RWS	70 Deg. F	237 grains / 2871 fps	48,500 CUP

750 GR. BARNES, LRS SOLID BRASS, Bore Riding Boat Tail, Molly Coated SPECIAL NOTE

The barrel for this bullet is throated .502" diameter for .350" longer than the standard .511" throat in "B" type rifle. Seat bullets so the front of the rear driving band is flush with the mouth of the case.

In the case of a standard .511 " throat only, you will have to seat the bullet further down into the neck to clear the lands and this reduces case capacity and raises pressures.

If you have to do this, reduce the starting load about 6 grains and expect reduced accuracy in relation to what might be had with the bore rider type throating.

750 GR. BARNES, LRS SOLID BRASS, Bore Riding Boat Tail, Molly Coated

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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*H5010	CCI #35	N/A	205 grains / 2513 fps	220 grains / 2697 fps
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*AA8700	CCI #35	N/A	205 grains / 2560 fps	220 grains / 2747 fps
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*H870	CCI #35	N/A	210 grains / 2584 fps	225 grains / 2769 fps
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*H50BMG	CCI #35	N/A	220 grains / 2581 fps	223 grains / 2734 fps
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*VV24N41	CCI #35	N/A	235 grains / 2618 fps	246 grains / 2716 fps
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*VV24N41	RWS	N/A	238 grains / ?	245 grains / ?
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*VV20N29	CCI #35	N/A	245 grains / 2581 fps	254 grains / 2731 fps
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*VV 20N29	RWS	N/A	242 grains / 2759 fps	252 grains / 2880 fps
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Best Load for Type "B" Rifle = 245 grains / 2794 fps

750 GR. HORNADY AMAX, Copper Jacketed, Lead Core, Aluminum Tip, (New Style 2.5" Long) Molly Coated

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
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VV 24 N 41	RWS	N/A	210 grains / ?	230 grains / ?
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*VV 24N41	RWS	N/A	197.5 grains / 2468 fps	212.8 gr. / 2692 fps
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Using a Non-Molly Coated AMAX Bullet

*VV 20 N 29	RWS	N/A	222 grains / 2516 fps	240.2 gr. / 2749 fps
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Using a Non-Molly Coated AMAX Bullet

H50 BMG	CCI #35	N/A	210 grains / ?	230 grains / ?
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With the old AMAX (2.7" length), the best accuracy using the VV 20 N 29 powder has come from about 214 grains with both CCI and RWS primers although the velocity is low, around 2350 to 2420 FPS. When using the new AMAX (length = 2.5"), accuracy has also been seen with the same powder in the neighborhood of 227 to 230 gr. with CCI and from 235 to 238 gr. with the RWS primers. .

**750 GR. HORNADY AMAX, Copper Jacketed, Lead Core, Aluminum Tip,
(New Style 2.5" Long) Molly Coated**

NOTES: Continued

The old Homady AMAX bullets measure 2.7" long and have a longer boat tail than the new version. These bullets will shoot fair at velocities under 2400 FPS. At higher velocities these earlier bullets seem to loosen the nose and can give erratic fliers at the higher velocities. Using a faster powder such as H50 BMG or AA 5010 & starting at 200 grains with the RWS primers might help accuracy. I'd recommend you molly-coat all of them.

Dave Emory of Homady has had good luck with 215 gr. of 50 BMG & CCI primers seated just off the lands with the latest run of new design Homady AMAX bullets. These measure 2.5 " overall length.

800 GR. BARNES, LRS SOLID BRASS, Bore Riding Boat Tail, Molly Coated

POWDER	PRIMER	TEMP	START LOAD/+V fps	MAX LOAD/+ V fps
*H5010	CCI #35	N/A	200 grains / 2490 fps	213 grains / 2652 fps
*AA8700	CCI #35	N/A	200 grains / 2560 fps	215 grains / 2747 fps
*H870	CCI #35	N/A	205 grains / 2464 fps	220 grains / 2666 fps
*H50BMG	CCI #35	N/A	212 grains / 2530 fps	225 grains / 2685 fps
H50BMG	RWS	N/A	220 grains / 2581 fps	233 grains / 2734 fps
VV24N41	RWS	N/A	215 grains / ?	244 grains / 2715 fps
*VV24N41	CCI #35	N/A	230 grains / 2562 fps	246 grains / 2678 fps
VV20N29	RWS	N/A	240 grains / 2500 fps	252 grains / 2830 fps
*VV20N29	CCI #35	N/A	240 grains / 2453 fps	254 grains / 2684 fps

The front driving band is .502 for a bore riding throat ahead of a standard .511 " throat. The heavy gun classes of FCSA are allowed to use a throat that tapers from .511" down to .502" in a minimum length, usually about .050" long.

800 GR. BARNES, LRS SOLID BRASS, Bore Riding Boat Tail, Molly Coated
Additional Notes: con't

This has a tendency to reduce the top end load that would be allowed with a longer throat. The best powder for competition seems to be the **VV 20 N 29** powder and RWS primers. This combination however is very temperature sensitive. At temperatures under 60 Degrees F., the groups tend to string vertically so you must keep the ammo warm when shooting this load combination.

At above 60°F though, this load has won a preponderance of matches in both Light and Heavy class, setting a lot of records in the process.

will be reduced. In order to maintain the best accuracy and performance, these barrels require more frequent cleaning. (Author: I personally recommend you molly coat any bullets, especially of the solid construction type to help alleviate the fouling. This will not replace the stringent cleaning protocol required for good barrel maintenance.)

In closing I'd like to take a bit to reiterate some things. One must remember that the thrust against the recoil lugs and the back of the cartridge case head goes up to the square of the diameter. Thus, when we work with a case as large as the 50 BMG you can have a lot of horsepower at the standard upper end of 52,000 lbs. of pressure generated by a top end load combination.

There is nothing mysterious about loading for the .50 but you must look at your rig and see if there is anything in the make up of it that could contribute to high pressures when loading. Take notes as you go along, you will find it isn't hard to extrapolate a loading with a different powder if you compare your accumulated notes as to what the gun acted like with other loadings.

Always start low and work up and take nothing for granted. A friend had been using solid bullets and went to a thin jacketed lead cored bullet. He thought that since the solid bullet didn't obdurate and had more engraving pressure that the same load would work. **WRONG!!** He found that the new bullet actually exhibited higher pressure signs as the bullet seemed to have **MORE** engraving pressure because of its makeup. He backed off about 8 grains and all was fine.

Now you have a better idea of why most ballisticians are either bald headed, or white haired. I'm working on both and don't consider myself to be a ballistician to start with.

While I have tried to be as accurate as possible, myself and all other quoted authors herein disclaim any liability for any damages which may result from the use of this data.

Thanks to the following people for their help putting this together.- AA = Accurate Arms reloading manual, Ted Curtis, & Marty Liggins. Barnes = Barnes reloading manual, Jessica Harrison. VV = VihtaVuori manual, Jeannie Bola. TCCI = Thunderbird Cartridge Co., Eric Luffy.

I'd like to thank everyone that gave their permission for me to quote from the various manuals and loading information for their time and effort in getting the information together. These people have given of their time and efforts to try and give you good components and the information to utilize them. Please be responsible and safe in your experiments with them and, if you happen to talk with any of them from time to time, an "attaboy" sure goes a long way toward making their day."⁴⁰

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As a final note to this reloading chapter. In a last minute phone call to Eric Williams he mentioned another powder that is being used. This is WC 886. It is a 25mm powder that is 14 percent nitro based. When used to drive the 800 grain bullet, reported velocities are in the 2,800 or 2,900 fps range.

This chapter was originally planned to be a short informative piece on the military ammunition and to show the technology in use in the civilian shooting sector. While the U.S. military may be restricted to using the standard issued cartridges, civilian and other military units may not be. In travels overseas while with the 1st SFGA, the author has seen many foreign special operations units show dynamic thought in developing ammunition. The Thai National Rifle and Pistol team that competes every year in the All Asian Rifle Matches dome some very good reloading and setup procedures. Their tests have a simple yet efficient approach. Since the Thai army broke the ground in respects to precision reloading for these matches, many other countries have followed suit in the race to win these matches. By the way, the first year the Thais competed with reloaded ammunition, they swept the matches.

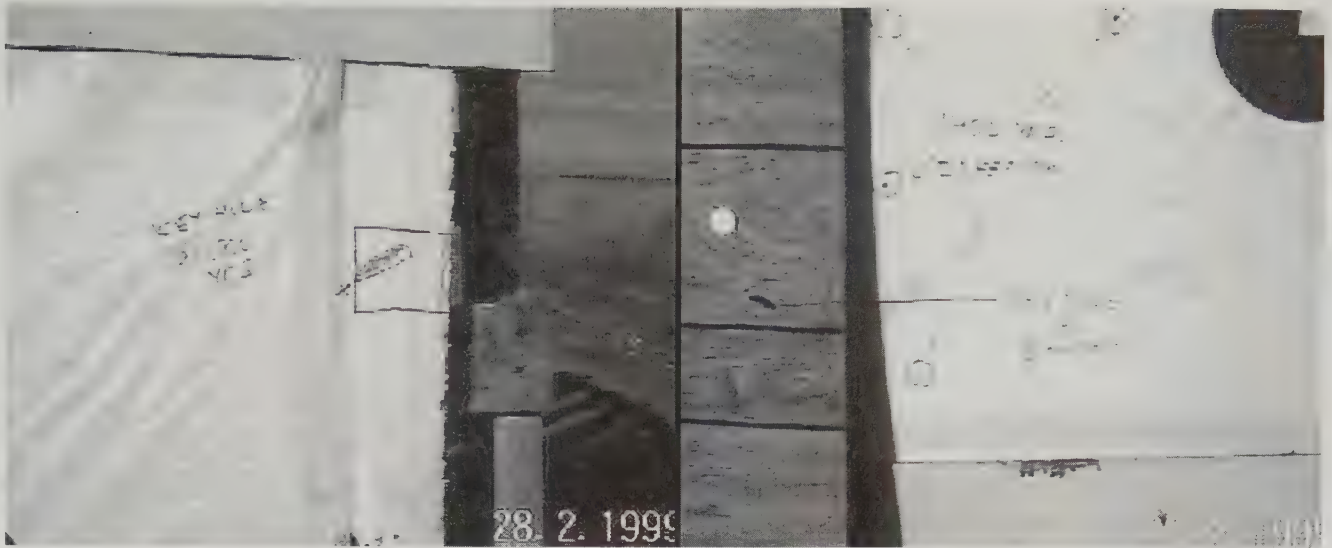
In my experience with the military .50 caliber rifles and their ammunition, many users and officers have stated that the guns were crap (refer to earlier in this book). In fact, in the vast majority of the cases, it simply was the military ammunition that was crap. Multi-component projectiles (Raufoss) cannot compare to solid bronze or steel CNC lathe-turned bullets. The ballistic co-efficient of these rounds are nearly double that of the military bullets. Their accuracy downrange is a gain of several hundred percent compared to accuracy shooting with military cartridges. The Raufoss greentip is the best, but it is NOT a 1 MOA cartridge in the best of the .50 caliber guns.

In a discussion with Eric Williams as this book was being finished we talked about projectile yaw. He stated that he has seen situations where a rifle and ammo would print an easy 1 MOA at shorter ranges, but then at 1000 yards, there would be vertical stringing of more than 20". His theory is that as the bullet clears the tip of the barrel, the gas drives into the muzzle brake around the bullet. It is possible that the muzzle brake activity is upsetting the bullet and inducing a yaw that is causing bullets to string up and down on the target.

These new bullets that are of the VLD design are much longer than the military bullets, however. These longer bullets tend to be upset easier as they approach the trans-sonic range. The shorter military bullets should be more resistant to this, and they would be if their construction wasn't so shabby. Remember back in the chapter on correcting for meteorological and environmental conditions? It was stated that operators must calculate their supersonic burnout range so that they don't shoot past the range at which the bullet is stable. To do so would greatly reduce their probability of hit on the target. While testing a .338 Lapua rifle earlier this year, I saw this first-hand.

The load was a 300 grain Sierra Matchking at a velocity of 2850 fps. Calculated supersonic burnout range was at about 1525 yards. On the target on the next page, you can see that the group is still sub-MOA at 1400 yards. The black circle to the upper right is an 8" diameter aiming point. However, note that at the 1500 yard mark, two out of three bullets keyholed and were spread across four feet on the target. Bullet runout for the 1500 yard shots was .0003". Runout for the 1400 yard shots were in a group of bullets from .0002" to .0003". Greater bullet runout will decrease the ballistic co-efficient and cause more long range instability. Combine that with the inherent instability of very long projectiles as they approach the transonic flight and you have problems. In this case, keyholing and severe loss of accuracy.

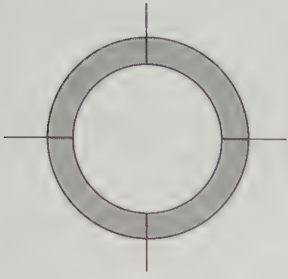
The research into long range shooting will continue. Powders get better as well as the other components. The great thing about competition shooting is that the shooters and builders are never satisfied and strive to redefine the state of the art for their rifles and ammunition. It will only get better.



FOOTNOTES

1. Reprinted with permission of Keith Pagel, staff columnist, *Very High Power Magazine*.
2. Credit: John Ferry, CW2, U.S. Army, retired, Boeing North America, Shreveport, LA.
3. Author's note: Visually, all bullets would appear the same. The Mark 211, Mod-0 round has an 11-degree angle on the boattail, while the others have 9-degree angle. The bullet weights are close enough to not be much of a real factor. The muzzle velocity for the Mark 211, Mod-0, M33 Ball and the M8API rounds are close enough to be the same (2715, 2735, 2735). There is considerable difference in the ballistic coefficients of the rounds, though (.649, .680, .663). This is explained later.
4. Author's note: To simplify this graph, note figure 8 Note the higher velocities that might represent the muzzle velocity of the gun is at the right of the graph. Look at the curve beginning at around 3,000 fps. Remember that the speed of sound under SAC is around 1,125 fps. As the bullet reaches this point on the graph, the BC value drops radically. It's the lowest at transonic flight. The value of the BC actually climbs quite high after the bullet is subsonic and settles down again. This is the curve of the ballistic coefficient of the different bullets in the test. Shooters that have read the Sierra books or any other reloading material have noted the printed ballistic coefficients for their bullets. Sierra lists several coefficients for differing velocity ranges, while other bullet makers list only one. The one that is listed is usually based on the formula on page 393. The actual BC is constantly changing in flight.
5. Author's note: Dr. McCoy makes a very good point about barrel twist in relation to accuracy. In some shooting communities this is common knowledge. The people that shoot the Palma matches (800, 900, and 1,000 yards with .308 rifles and iron sights) sometimes will have a different twist rate in a different gun for each range. Optimally, a barrel is twisted for a specific bullet and a specific range (purpose built). However, this is not practical and the selected twist rate is a compromise. Dr. McCoy suggests that the above three rounds would do better with a 1:18" twist rate. So why does the common .50 BMG gun still use a 1:15" twist?
6. Author's note: Sciacci's method may be outdated, and without a doubt using a single ballistic coefficient for an across-the-board table causes errors. The .50-caliber tables referred to in this book go well into the subsonic range. A different ballistic coefficient is used at each 100 meter interval in the creation of these tables. The tables are not generalizations and averages. There is another method for determination and accurate G1 ballistic coefficient. It involves measuring the muzzle velocity at the gun and then entering the number of minutes of angle required to hit a target at a given range (57.75 MOA at 1,300 meters for example). By going to Table II of the Ingall's Ballistics Tables you can determine, very accurately, the BC every 100 meters for your gun/load/bullet combination. it is exceedingly accurate and takes into account the varying BC based on transonic and subsonic flight.
7. Credit: Dr. Bob McCoy, reprinted with permission of the FCSA, VHP 1996 #4.
8. Author's note: Any references to points of attack do not reflect suggested points of attack by the author of this book. Nor do they reflect the points of attack mentioned in official U.S. military manuals or documentation.
9. Varying BC based on transonic and subsonic flight.
7. Credit: Dr. Bob McCoy, reprinted with permission of the FCSA, VHP 1996 #4.
8. Author's note: Any references to points of attack do not reflect suggested points of attack by the author of this book. Nor do they reflect the points of attack mentioned in official U.S. military manuals or documentation.

9. Author's note added.
10. Military designation is the Mark 211, Mod-0. The Mark and Mod are Navy designations versus the M designation used by the Army.
11. Author's note: The effects are quite spectacular on targets where you can see the zirconium incendiary splash through the target material.
12. Author's note: All Raufoss ammunition that has been seen in the last few years has the WCC followed by a year headstamp, and is manufactured in the United States.
13. The date of this article is 1993. The headstamp has changed to WCC since that time. No cartridges in the field are seen with the .50 FNB 91 headstamp.
14. Author's note: The twist ratio for a .50 SLAP round is radically different than for the standard rounds. It will not be printed here for security reasons. The SLAP round is exceedingly lethal for extreme range shooting as the penetrator is supersonic for more than 2,500 meters under SAC.
15. Author's note: The Accelerator was added to this section because of a lot of questions that the author has fielded concerning this cartridge. There has been an interest in the sniping community in this cartridge for use in sniper weapons systems. The cartridge as offered is very inaccurate. Clearly, part of this inaccuracy lies in an incorrect twist rate for this penetrator. A rifle would have to have a special barrel for the SABOT penetrator.
16. Author's note: This dispersion requirement is for the .50-caliber machine gun, which is going to have a 1:15" twist rate. As previously stated, this twist rate is not optimum for accuracy.
17. Credit: Eric Williams, VHP 1993 #2. Letters reprinted by a shooter in Houston, Texas, and from Keith Pagel, Lexington, Ohio.
18. Credit: Eric Williams and Skip Talbot, FCSA members, VHP 1994 #4.
19. For the military users and trainers on this subject.
20. There are a few rifles made in the U.S. that can be chambered for the 12.7mm Soviet round. When the M600 was built by Daisy, it was available in this loading. The AWT by Greece is also available in the 12.7mm Soviet.
21. Gale McMillan's notes on "bullets going to sleep" in a letter to VHP 1997 #4, p. 37.
22. Buddy Clifton's notes on "bullets going to sleep" in a letter to VHP 1997 #4, p. 37.
23. This article is very technical in nature and may be above some heads out there. It offers a very unique insight into the materials used for bullet construction for match grade bullets. The article also reinforces previous comments about the different twist rate requirements for the material of the bullet alone. Much credit to Mr. Daniel Lilja for this article and on the fine barrels he makes. VHP 1996 #2.
24. Major Econ used a Corbin press and dies to make his bullets.
25. Credit: Eric Williams, VHP 1993 #4.
26. The barrel throat is the area where the bullet is essentially "squeezed" into the barrel. This is done to avoid a heavy "collision" with the bullet impacting on the lands in the barrel at a 90-degree angle on the leading edge of the land.
27. Credit: Skip Talbot, VHP 1994 #2.
28. The above bullet design is by Richard B. Near and was published in VHP 1994 #2.
29. Credit: Richard B. Near, VHP 1994 #2.
30. Credit: Eric Williams, VHP 1993 #2.
31. This data is for the machine gun barrel only, not the barrels on military .50-caliber sniper rifles.
32. Credit: Skip Talbot, FCSA, VHP 1993 #2.
33. Author's note: Military shooters—here's another good bit of information that explains why the dreaded M33 Ball has such erratic accuracy problems. At times it shoots acceptably well, then there's a few mean flyers that leave you scratching your head.
34. Credit: Eric Williams, VHP 1993 #1.
35. Credit: Eric Williams, VHP 1992 #4.
36. Credit: Jack Hollinger, VHP 1994 #1.
37. Author's note: The handloaders are the group that military reloaders will likely be a part of.
38. Credit: Dan Zignego, VHP 1994 #4.
39. Author's note added.
40. Credit: Skip Talbot, FCSA, VHP 1998 #3.



Glossary

-A-

Anemometer. This is a device used to measure wind velocity.

ART Scopes. These Automatic Ranging Telescopes were made famous for their use during the Vietnam War. They were used on various rifles in the ART I and ART II configuration. The Army M-21 used both configurations well into the 1990s and are still in use in Army Special Forces units today.

-B-

Ballistic Cam. A ballistic cam is actually a device on a rifle scope that resembles a cam shaft lobe in shape. It is around the scope tube and rides a spring-loaded plunger on the scope base. There are numbers on the cam ring that represent hundreds of meters or yards. As you dial the number corresponding to the range, the shape of the cam either raises or lowers the angle of the scope tube. The advantage of this is that you are always looking through the center of the lenses in the scope tube. There is no optical vignetting. The term Ballistic Cam is often misused in place of Bullet Drop Compensator. BDCs only move parts inside of the scope tube and subject the shooter to errors induced by optical vignetting.

Ballistic Coefficient. This is a numerical definition of the ability of a bullet to resist air drag. It is based on a simple relationship between the bullet's length, weight, shape, diameter, and velocity at a point downrange. This BC number is stated as a comparison to a "perfect bullet." That bullet is assigned a value of 1.0000. Refer to the firing tables for the Mark 211, Mod-0 cartridge. At the bottom of the table, the printed ballistic coefficient is .6001. You should know that this is an average of over 2,500 meters. This includes transonic and subsonic flight, both of which affect the BC radically. The true ballistic coefficient (or flight coefficient, as it used in these custom tables) changes based on the muzzle velocity of the gun, and when

plotted on a curve resembles a sine wave when compared to the BC values as the bullet travels downrange. The BC numbers start out high and drop off as the bullet approaches transonic flight. At subsonic flight (immediately after transonic flight) the BC is at its lowest point. As it travels even further downrange and stabilizes after its transonic disruption, the BC numbers begin to climb again.

Barrett “Christmas Tree” Reticle. A reticle pattern used by Barrett Firearms on their .50 caliber rifles. It is calibrated for M33 Ball only for ranges from 500 to 1,800 meters.

Battery Fire Procedures. A method of engagement in which more than one gun (up to three guns) is under the control of a single observer. Guns are fired in battery, simultaneously onto a single or multiple targets. This is done to reduce exposure time, or to ensure a higher probability of a hit in a high-threat environment.

Bona Fides. This is an exchange of information between two individuals consisting of codewords or key phrases. They are issued to each of the meeting parties by their higher chain of command. Bona Fides are exchanged between these two parties who have never met before to ensure they are who they say they are.

Boreriders. Boreriding bullets are bullets machined from solid steel, brass, or bronze. These bullets have a diameter that is matched to the internal bore of the gun as measured from the top of the lands. The entire bearing surface of the bullet (Bourrlet) does not engage the rifling. (The bullet has a typical outer diameter measurement of .502 inch. A typical land to land measurement of a .50 BMG barrel is .501 inch.) A driving band, typically .080-inch long with a outer diameter of .511 inch, is near the end of the bearing surface that is actually engaging the rifling. This reduces the barrel wear and heat generated by driving solid metal bullets down the rifled barrel using the entire bearing surface of the bullet to engage the rifling. Boreriders have always been used on cannon projectile design and are fairly new to the “small arms” bullet world.

Bullet Drop Compensator. A bullet drop compensator is a type of elevation knob used on optical sights. A BDC is specified for a specific cartridge, using a specific bullet, at a specific muzzle velocity. Typically on the BDC knob there are numbers (usually from 1 to 10) that indicate the range in hundreds of yards or meters. When a particular number is dialed to the index mark, your projectile will strike your point of aim at that range (not taking into account the meteorological and environmental conditions). These BDC knobs are set for a standard atmospheric condition of 59 degrees Fahrenheit, 29.53 In. Hg, 70 percent relative humidity, and no slant angle to the target. Examples of BDC type scopes include the USMC Unertl 10X used on the M40 rifle, the Leupold & Stevens Mark IV, M-3 or the M-3A Ultra scope, and Swarovski ZF series scopes. There are others—these are just 3 that are available.

-C-

CARVER Matrix. This is a decision support matrix for targeting of a military/civilian target. C - Criticality, A - Accessibility, R - Recoverability, V - Vulnerability, E - Effect on Population, R - Recognizability.

Combination Day/Night Vision Systems. These are sights that have integrated day and night vision technology. The new AN/PVS-10 is the best example of this system. There is a lever that physically is moved to switch the sight from the day mode to the night mode.

-D-

Danger Range. A term used to describe a part of the trajectory in which the bullet is traveling below the height of the target. This may occur both before and after maximum ordinate. In cases where the maximum ordinate is lower than the height of the target, the entire distance from the gun to the target is danger range.

Danger Space. Danger space is a horizontal measurement expressed in yards or meters. As the bullet goes past the maximum ordinate and travels downward toward impact with the ground (ignoring the target), the danger space measurement begins at the point where the bullet is equal to the top (height) of the target and continues to when the bullet impacts the ground, again ignoring the target.

Dedicated Night Vision Systems. These are night vision systems that stand alone or are not attached to a day optical sight. Examples include the Litton-995 Night Ranger, Litton Aquila, AN/PVS-4,5,15, etc. Typically they do not have a bullet drop compensator, though the M-995 does.

-E-

ENV Conditions. For this book's use, ENV (environmental) conditions are the slant angle to the target, relative wind direction, and temperature of the ammunition.

External Ballistics. The science of external ballistics involves the projectile in flight from the time it has cleared the muzzle to the point at which it impacts the target. To understand the methodology of correcting for meteorological and environmental conditions, you must understand some basics about external ballistics.

Extreme Spread. The greatest measurement between the two shots that are furthest apart in a group of shots.

-F-

Fall Angle. The fall angle is the degree of arc that represents the bullet's trajectory as it impacts the target. This is also referred to as the striking angle.

.50 BMG. An unofficial term for the .50 caliber Browning machine gun cartridge as coined by the Fifty Caliber Shooter's Association.

Flight Time. This is the bullet's time of flight in milliseconds from the muzzle of the gun to the target. This data is used in determining many technical factors. We will stress the use of this to determine if there is enough time for the bullet to travel to the target before the target bobs out of view. (This may be because the target is a radical mover and cannot sit still, for example.)

FOB (Forward Operating Base). In a Special Forces company, the FOB is usually the Company Level Headquarters, aka the "B" team. FOBs are also mission launch sites for SF teams and operations.

-G-

Gyroscopic Precession. This is the motion that a bullet has when it is in flight. Sometimes this effect is minimal and sometimes it is so bad as to have a negative effect on the flight of the bullet. It is likened to a quarterback's pass—sometimes it flies perfectly along its trajectory with no coning motion. Other times it has a pronounced wobble that bleeds off energy and range faster. This has many causes. One of the common

causes in military ammunition is the core of the bullet not being precisely located in the center of the bullet. This effect does stabilize with range. It is a common reason that some rounds will group poorly at close range and get better as the range increases.

-H-

Heavy Rifles. Rifles classified within U.S. Special Operations that are in the caliber .50 BMG and larger. Typical expected engagement range is 1,500 meters and beyond. Example: .50 BMG, 14.5mm Soviet.

High Contrast Visual Identification Capability (HC-VIC). This is where the operator places an object with high contrast colors (such as black and white) downrange under varying illumination conditions. This is the “High Contrast” target. For example: Use a number board about a foot in height with a 9-inch number painted on it. Use contrasting colors (black on white) and record under what percent illumination you can clearly see that number. Record the changes that occur as the percent of illumination changes. Also record the position of that illumination when the source is the moon or other low level ambient light.

Hit Probability (Ph). When a number of shots are fired from a rifle under the same MET and ENV conditions, it will be found that the shots have not fallen on the same spot but are grouped around a point on the target. Generally, this is due to deviations in the muzzle velocity and the initial yaw and pitch of the bullet as it leaves the barrel. This scattering of shots due to these unavoidable conditions is known as dispersion. Because of this dispersion, at long ranges (1,500 meters+) unless the target is large, a number of shots will miss even when all operator and calculator inputs are correct. A team determines its hit probability by shooting individual and battery-fired shots at targets at varying ranges. Impacts within the minute of angle requirement (usually 2 MOA) are divided by the total shots fired. This percentage is the Ph for the individual/team at that range with the fired ammunition.

-I-

Internal Ballistics. The term internal ballistics deals with everything inside the firearm. For the sake of definition, let's call internal ballistics that part of ballistics that deals with firing the projectile down the bore inside the firearm. From the pull of the trigger, the release of the sear, the striking of the firing pin, the ignition of the primer and propellant, the projectile moving down the bore, and up to the point at which the bullet leaves the muzzle of the barrel. Other areas include the chamber pressure, lock time and headspace. In relation to this chapter, internal ballistics deals with changes in muzzle velocity due to “hot” or “cold” ammunition.

Isolation. As used by U.S. Army Special Forces. A term used to describe a Special Forces team's pre-mission activities. The team is isolated for mission planning and rehearsal purposes.

-L-

Light Rifles. Rifles classified within U.S. Special Operations that are any caliber up to and including 7.62mm NATO. Typical expected engagement range is up to 600 meters.

Line of Bore (LOB). This is an imaginary line measured in degrees and minutes of angle that the barrel is elevated to send the bullet traveling to the target.

Line of Sight (LOS). This is the sight line of the shooter through the optical or iron sight system to the point of aim. This is often confused with the Line of Bore.

Low Contrast Vision Identification Capability (LC-VIC). This is where the operator places an object with low contrast colors (camouflaged objects) downrange under varying illumination conditions. This can be done by dressing a dummy in BDU's (Battle Dress Uniform) or neutral pattern clothing and standing that next to the target and recording your ability to see this at this range under the same rules in the above checklist item. Use low contrast colors, record under what percentage illumination you can clearly see that number. Record the changes that occur as the percentage of illumination changes. Also record the position of that illumination when the source is the moon or other low-level ambient light. Determining a team/system's HC-VIC and LC-VIC is an excellent mission planning tool.

-M-

Maximum Performance Envelope. A term to describe shooting at the range where the bullet is nearly at transonic or subsonic velocities as it approaches the target. For many projectiles this is the maximum range at which high precision can be expected.

Mean Radius. This is a unit of measure used to depict a gun system's level of accuracy. A number of shots are fired at a target at a specific range. The center of the group is calculated and then the distance is measured from that center of group to each individual shot in the group. This measurement is averaged and called the mean radius.

Medium Rifles. Rifles classified within U.S. Special Operations that are any caliber larger than 7.62mm NATO, up to, but not including .50 caliber BMG. Typical expected engagement range is up to 1,200 meters. Example: .300 Winchester Magnum, .338 Lapua.

MET Conditions. For this book's use, MET (meteorological) conditions are the air temperature and barometric pressure.

MOA. Minute of Angle. A unit of measure used in sniping and other shooting disciplines equal to 1/60th of a degree. Roughly 1 MOA at 100 yards = 1 inch, or 3 centimeters at 100 meters.

Mil, Mils. Milliradians (MIL) are units of measure. Generally, there are 3.375 MOA per mil. 1 mil at 1,000 yards = 1 yard. 1 mil at 1,000 meters = 1 meter.

Muzzle Brake Induced Error. This effect occurs when one is shooting a large bore (.50 BMG) rifle that is equipped with a venting-type muzzle brake. A shooter that is muscling his gun onto the desired point of impact on a target will experience this effect. As the bullet begins to travel down the bore, the cold air (precursor) in front of the bullet enters the muzzle brake and the brake starts to pull the rifle from the shooter's shoulder. This also causes the gun to be further pulled in the direction that the shooter is muscling the gun (muscled to the right, bullet will impact even further to the right). The MBIE effect is one of the biggest causes of misses on targets or errant fliers in a group of shots.

Muzzle Velocity. This is the speed of the bullet as it exits the muzzle of the rifle. This data is usually measured at a set distance downrange. The actual muzzle velocity is calculated and corrected from this point. It is important that the muzzle velocity data you examine has the distance of the measurement from the

muzzle data available. To develop firing tables from the Ingalls Ballistic Tables you must have a measured muzzle velocity for your rifle and load combination.

-N-

NSWG - Naval Special Warfare Group. There are two such groups: NSWG 1 and NSWG 2.

-O-

OPLAN/OPORD. An Operations Plan is a military unit's plan to execute a mission. Many times OPLANs are developed to cover specific emergencies and contingencies. Resources are allocated and units are assigned, then the plans are shelved until they need to be implemented. The OPLAN becomes an Operations Order when it is to be executed and details and time lines are developed.

Optical Vignetting. This is a visual distortion that occurs when you look through a lens or set of lenses near the edges rather than near the center of the lenses. Vignetting occurs in scopes where you have an internal adjustment and the erector cell is moved up or down. The reticle is no longer looking through the center of the lens and is looking through the outer one-third of the lens, for example. Because of the resulting distortion, you are not looking at what you think you are. The image is not directly behind the reticle and misses may occur. On scopes that are externally adjusted or use ballistic cams and the ENTIRE scope moves, there is no vignetting effect.

-P-

Piggyback Night Vision Systems. The piggyback systems are night vision devices that attach in some manner to the day scope. The SIMRAD and NADS series mount on the top of the scope and reflect the image into the objective lens of the scope through a set of mirrors. Other piggyback systems such as the Remington, ITT, and systems offered by Seiler Optical and U.S. Optics, have systems that are built into the scope between the ocular lens and the elevation/windage turrets.

Point Blank Zero. Point blank zero is a method of engagement for both materiel and human targets that eliminates the requirement for range estimation, to a point. This mid-range engagement technique uses the curve of the trajectory to the shooter's advantage. This method allows the shooter to engage targets by using a center of hold that is the center of the diameters listed under "Kill Zone" in the table Chapter 9. When the shooter aims at the center of this diameter, he is accepting that the bullet will strike somewhere, vertically, in that size of kill zone.

-R-

Raufoss. AKA Mark 211, Mod-0, AKA "Greentip," also NM149. This is the explosive, incendiary, armor-penetrating projectile that is the standard cartridge used in U.S. Special Operations.

Remaining Velocity. This is the bullet's velocity when it impacts the target. (This is also known as the impact velocity.)

Reverse Image Zero. The RIZ is a method of engagement that uses the dimensions of the trajectory to engage targets of unknown distance without determining that distance first. The concept of the Reverse Image Zero isn't all that new. Essentially a range is selected and the gun zeroed at that range where the

maximum ordinate of the bullet is not higher above the ground than the height of the targets expected. By aiming at the feet or their visualized location, the trajectory of the bullet never rises higher than the target's head. If a target were between 100 meters and 90 percent of the zero range, the rounds would strike that target in a killing zone 1 meter high on the front of that target. It was only recently rediscovered and modified to apply to modern rifles with better trajectory performance. The earliest reference to Reverse Image Zero (referred to in this material as the Negative Angle Sighting) I could locate is in *The Theory of the Rifle and Rifle Shooting*. Lt. H. Ommundsen advanced the idea of a negative angle sighting toward the beginning of 1912. Sir George Greenhill advocated it in a lecture at the Institution of Electrical Engineers on the 19th of January 1912. "With a certain rifle and ammunition select a trajectory, the greatest height of which is twice that of the target desired to hit." For instance, with the service short rifle and Mark VII ammunition an 11 foot high trajectory (that is to say, a trajectory, the maximum ordinate of which is twice the height of an average man) is given with a range of something under 700 yards.

-S-

SFOB. Special Forces Operational Base. This can be a C3I unit for Special Forces teams that is above the FOB level. It is commonly manned by SF Battalion or SF Group staffs.

Single Shot Hit Probability. This is a figure given in percentages that gives a reader the probability of hitting a target of a given dimension for whatever range the SSHP is calculated. There are many methods of determining the SSHP of a sniper/rifle/ammunition combination.

Slant Range. Slant Range is the True Range corrected for the angle of the gun to the target. When you have an angle to the target, the slant range figure will always be the smaller of the two. Slant Range is important because the bullet is exposed to gravity for a shorter duration than when shooting on flat ground. The slant range elevation setting (when used) is the first elevation setting put on the scope. The slant range setting is not used to correct for air temperature, barometric pressure, or the winds.

Spin Drift. Spin drift is a by-product of gyroscopic precession caused by a right hand (or left hand) twist of a rifled barrel. A bullet exits the bore with a tremendously high RPM—in fact, the bullet rides on a column of air as it travels downrange. As the bullet is spinning there is lower air pressure on the side the bullet is spinning toward, which causes the bullet to drift in the direction of lower resistance. One problem associated with spin drift is in bullets that have excessive runout (bullets not perfectly aligned in the case). Excessive runout increases air resistance and increases drift so the bullet will destabilize faster and tumble sooner. Spin drift is treated very lightly in military circles. While most military sniping ranges are at ranges where bullet drift is of little consequence, when shooting at 1,500+ meters, nothing can be ignored.

Subsonic Flight Range. This is the range where the bullet is traveling at velocities less than 1,125 fps. The bullets actually fly quite smoothly during subsonic flight. Bullets that are fired at a subsonic velocity usually are quite accurate if the barrel twist is correct for such a flight. Ballistic coefficient values will actually climb back high after transitioning to subsonic flight (where they are they lowest). One reason that high-angle fire (artillery and naval gunfire) is so accurate is that the launch velocities are subsonic.

Supersonic Flight Range. The maximum range at which a projectile is traveling at a velocity greater than 1,125 fps. At these speeds there is still a small sonic crack downrange that can be detected by the opposition. When tied with the maximum performance envelope and maximum effective range, the supersonic flight range is the maximum effective range.

Swept Space. This is a horizontal measure that changes with the lay of the ground. Swept space is the linear measurement of the cone of fire created by shots placed at the top of the target and those placed at the bottom of the target. This is a little difficult to put into words. There are two rules that apply to swept space versus danger space: On ground that is rising in front of the shooter, the swept space dimension will decrease; on ground that is falling away from the shooter or sloping downhill, the swept space dimension increases and may easily continue for hundreds of meters.

-T-

Target Indicators. These factors are grouped into four major areas: olfactory, tactile, auditory, and visual. They are things that an individual does or does NOT do which result in his detection by an enemy force. Target Indicators are also used by the friendly force sniper to detect the presence of enemy personnel. These factors do not just apply to snipers and sniper operations. They are part of the overall camouflage game.

TC 23-13. U.S. Army Sniper Training and Employment. This is the regular U.S. Army's Sniper Training and Employment manual.

TC 31-20-4. The Special Operations Sniper Training and Employment Manual. This is the manual written and printed by the Special Operations Target Interdiction Course at Fort Bragg, NC.

Terminal Ballistics. Terminal ballistics studies the path of the bullet and its effects once it makes contact with any medium other than air. This ranges from what happens to the bullet to wound ballistics of the target itself.

T-Gewehr. German term for anti-tank rifle.

Trajectory. This is the actual path that the bullet takes once it has left the muzzle until impact with the target or another medium. External ballistics is the study of these phenomena. Within the trajectory are the following components.

Rising Branch. This is the part of the trajectory in which the bullet departs the muzzle of the rifle and rises (when the muzzle is elevated) in flight until it reaches the maximum ordinate.

Mid-Range Trajectory (MRT). This is the height the bullet reaches at the true mid-range to the target. For example on a 1,000-yard shot, the MRT occurs at exactly 500 yards. This term is frequently confused with maximum ordinate.

Maximum Ordinate. This is the highest point the bullet reaches along its trajectory. This is measured from the Line of Sight as you look through the sights to the target, not from the ground or from the line of bore. This occurs at different ranges with different cartridges and weapons. Maximum Ordinate will never occur before the MRT. Reviewing the data book will indicate that the maximum ordinate occurs farther than the MRT as the range increases. Maximum ordinate will be the focus of much field firing during this sniper course.

Falling Branch. This is the part of the trajectory in which the bullet has reached its maximum ordinate and is now beginning its downward flight to the target. This terminates at the target or any other medium.

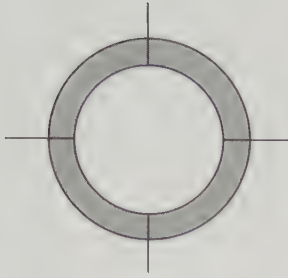
Transonic Flight Range. This is a short distance in which the bullet is slowing down to subsonic flight.

At these ranges, the supersonic shockwave is 90 degrees to the line of flight. This is also the range at which a bullet may destabilize enough to yaw, pitch, and/or tumble. A bullet goes through the same disturbances that a jet aircraft does slowing down through the sound barrier. For many projectiles, striking small targets anywhere past this range takes a great deal of luck.

True Range. The true range to a target is a measurement in yards or meters from the gun to the target, regardless of the shooting angle. In essence, it is the amount of air between the gun and the target. It is important because True Range is the figure that you always use to correct for MET and ENV conditions. When you have a slant angle to the target, the True Range elevation setting WILL NOT be placed on the scope. It is only a number used to correct for the MET and ENV conditions. The winds are based on the True Range. Whether you are shooting on flat ground or straight up in the air 1,000 meters is always 1,000 meters regardless of the angle.

-W-

Wildcat Cartridge. This refers to a cartridge that is altered to accept a bullet (usually smaller than the original diameter) other than the one it was designed for. A good example is the .338 Lapua Magnum. This was originally a wildcat. It was made by stepping down the neck on a .416 Rigby case to accept a .338 diameter bullet, then known as the .338/.416 Rigby.



Acronym List

-A-

AAA - Anti-Aircraft Artillery
ACOG - Advanced Combat Optical Gunsight
ADA - Air Defense Artillery
ADM - Acquisition Decision Memorandum
AFSOC - Air Force Special Operations Command
AP - Armor Piercing
APDS - Armor Piercing Discarding Sabot
APDST - Armor Piercing Discarding Sabot - Tracer
API - Armor Piercing, Incendiary
APIT - Armor Piercing Incendiary, Tracer
APFSDS - Armor Piercing, Fin Stabilized, Discarding Sabot (a type of penetrating projectile)
ASL - Above Sea Level, referring to altitudes above sea level. 5000' ASL
ART - Automatic Ranging Telescope

-B-

BDU - Battle Dress Uniform
BDC - Bullet Drop Compensator
BLS - Beach Landing Site

-C-

CARVER - See Definition List.
CAS - Close Air Support
CCC - Cross Cultural Communications
CCTV - Closed Circuit Television
C&E - Communications & Electronics
CEOI - Communications, Electronics Operating Instructions
CIS - Commonwealth of Independent States, formerly some countries of the Soviet Union.
CG - Commanding General
CNC - Computer Numerical Control, a precise method of controlling a milling or lathe operation
COA - Course of Action
COMBLOC - Communist Bloc, weapons, personnel, and equipment of the old and current Communist block of countries
CQB - Close Quarters Battle, or **CQC** - Close Quarters Combat
CSAR - Combat Search and Rescue
C3I - Command, Control, Communications and Intelligence
CUP - Copper Units of Pressure

-D-

DARPA - Defense Advanced Research Projects Activity
DARS - Designated Area for Recovery
DCD - Directorate of Combat Developments. Another entity within USAJFKSWCS.
DOD - Department of Defense
DZs, LZs, PZs - Drop Zones, Landing Zones and Pick-up Zones
DOTD - Directorate of Training and Doctrine, an entity of USAJFKSWCS
DTG - Date/Time Group

-E-

EDM - Electro-Discharge Machining
ENV - Environmental, as in Environmental Conditions
EOD - Explosive Ordnance Disposal
EPA - Evasion Plan of Action
E&R - Escape and Recovery, this used to be referred to as E&E (escape and evasion)
EVC NJ -38C - The acronym EVC refers to Evasion Chart. These are specialized maps printed on a highly durable material and issued to pilots and special operations personnel where escape and recovery behind enemy lines is possible
EX or X - Experimental

-F-

FCSA - Fifty Caliber Shooter's Association
FEBA - Forward Edge of Battle Area
FFP - Final Firing Position
FFU - Forward Friendly Unit

ACRONYM

50 BMG - .50-caliber Browning Machine Gun
FLIR - Forward Looking Infra Red
FLOT - Forward Line of Troops
FMFLANT - Fleet Marine Force, Atlantic
FPS - Feet Per Second
FSWS - Family of Sniper Weapons Systems. The light-, medium-, and heavy-class guns
FOV - Field of View
FOB - Forward Operating Base

-G-

GCLP - Ground Commander's Laser Pointer
GMCS - Guiding Metal Clad Steel
GPS - Global Positioning System
GSR - Ground Surveillance Radar

-H-

HC-VIC - High Contrast Visual Identification Capability
HE - High Explosive
HEIAP - High Explosive, Incendiary, Armor Piercing
HLZ - Helicopter Landing Zone
HP - Hewlett Packard
HSR - Heavy Sniper Rifle
HTI - Hard Target Interdiction

-I-

IAD - Immediate Action Drill
IR - Infra Red, part of the light spectrum, IR is in the non-visible spectrum.
ISS - Integrated Shooting System
I-T - Incendiary, Tracer

-J-

JMEM - Joint Munitions Effectiveness Manual
JOS - Joint Operational Stocks Warehouse, Lexington, Kentucky
JSOA - Joint Special Operations Area
JSSAPP - Joint Services Small Arms Procurement Program
JRCC - Joint Resolution Casualty Center
JRTC - Joint Readiness Training Center

-K-

KD Range - Known Distance Range
KIA/WIA - Killed in Action/Wounded in Action

-L-

LAD - Light Amplification Devices
LC-VIC - Low Contrast Visual Identification Capability
LOP - Length of Pull
LTD - Laser Target Designator

-M-

MACVSOG - Military Assistance Command, Vietnam, Studies and Observation Group
MAROPS - Maritime Operations
MAU - Marine Amphibious Unit
MBIE - Muzzle Brake Induced Error
MER - Maximum Effective Range
MET - Meteorological, as in Meteorological Conditions
METL - Mission Essential Task List. This is a unit's list of necessary missions needed to accomplish their overall stated missions
METT-T - Mission, Equipment, Terrain, Troops Available and Time
MGRS - Military Grid Reference System
MILSPEC - Military Specification
MITASK - Mission Tasking
MOA - Minute of Angle
MNS - Mission Needs Statement, a document generated by field units to bring command attention to a shortage of a piece of equipment needed for a unit's mission. Similar to an Operational Requirements Document.
MPE - Maximum Performance Envelope
MSR - Mission Support Request
MSS - Mission Support Site
MTT - Mobile Training Team

-N-

NADS - Night Augmented Day Scope
NAVSPECWARCOM - Navy Special Warfare Command
NMC - The National Match Course of fire. This is a 50-shot course of fire shot at 200, 300, and 600 yards using the standing, sitting, and prone position. Another version of the NMC is an 80-shot course of fire
NSWC - Naval Surface Warfare Center
NSWC-C - Naval Surface Weapons Center, Crane Division, Crane, IN
NSWG - Naval Special Warfare Group
NVEC - Night Vision Equipment Company
NVD - Night Vision Device, or NODs - Night Observation Device

-O-

OBS - Observer
OPLAN - Operations Plan

ACRONYM

OPORD - Operations Order
OPSEC - Operational Security
ORD - Operational Requirements Document
ORP - Objective Rally Point

-P-

PACE - Primary, Alternate, Contingency and Emergency. The term PACE is used to cover all the means of communications backups that a team will use on the ground. The thinking is that 4 levels of redundancy will cover 99 percent of all common problems
PBZ - Parallel Bore Zero
Ph/PK - Probability of Hit / Probability of Kill
POA - Point of Aim
POI - Point of Impact
PRODAS - Production Design / Analysis System. A program by General Electric for designing and analyzing the design of projectiles
PTRD -
PzB - Panzerbuchse Modell

-R-

RAI - Research Armaments Industries also referred to as Reddick Armaments Industries. Rifles made by RAI were also known as "Haskins" guns.
RIZ - Reverse Image Zero

-S-

SAFE - Safe Area for Evasion
SAR - Search and Rescue
SASR - Special Application Scoped Rifle or Special Application Sniper Rifle
SATCOM - Satellite Communications radio systems
SDS - Sniper Detection Systems
SERE - The US Army USAJFKSWCS's Survival, Evasion, Resistance and Escape school at Fort Bragg, North Carolina
SFGA - Special Forces Group (Airborne)
SFOB - Special Forces Operational Base
SFODA - Special Forces Operational Detachment - Alpha
SLAP - Saboted Light Armor Penetrator
SO - Special Operations
SOA - Special Operations Area
SOF - Special Operations Forces
SOI - Special Operating Instructions
SOP - Standard Operating Procedure
SOT-A - Support Operations Team - Alpha
SOTIC - Special Operations Target Interdiction Course
SPIES - Special Patrol Insertion/Extraction System. A system for inserting or extraction up to 10 members of a patrol

SRT - Special Reaction Team

SSHP - Single Shot Hit Probability

SSIS - Scout Sniper Instructor School

STABO - Another insertion and recovery system. The term STABO is a combination of the last names of the two men that devised the system during the Vietnam war

SWS - Sniper Weapons System

SWTG - aka **1st SWTG** - Special Warfare Training Group, an entity within USAJFKSWCS.

1st SWTG contains 3 Battalions all training different types of special operations courses. SOTIC fell within D Company, 2nd Battalion

-T-

TI - Texas Instruments

TCCI - Thunderbird Cartridge Company, Incorporated

T/CT - Tracking/Counter-Tracking as in countermeasures

TO&E - Table of Organization and Equipment, a table used in the Army that outlines a unit's allowable equipment and their established organization

TRP - Target Reference Point

-U-

USAJFKSWCS - United States Army John F. Kennedy Special Warfare Center and School

USASOC - United States Army Special Operations Command

USMCMEU - U.S. Marine Corps Marine Expeditionary Unit

USSOCOM - United States Special Operations Command

-V-

VHP - Very High Power Magazine

VLD - Very Low Drag, a bullet design

-X-

X or EX - Experimental



Reproducible Forms and Data Pages

22.76

2 MOA TARGET

1000 MPROBABILITY OF HIT SHEET

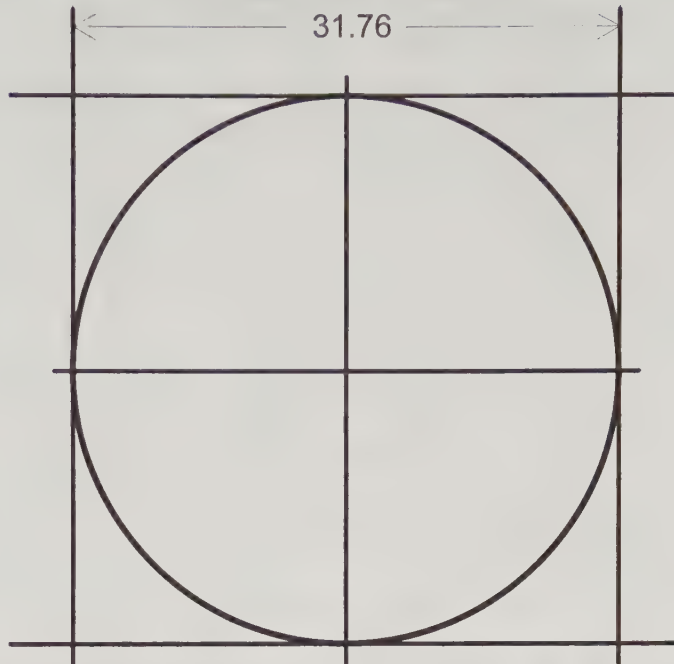
SLANT ANGLE CORRECTION

SAC Elevation Setting Correct ELev. Data Used on Gun

BP	TEMP	AMMO TEMP

	SS	SS	SS	SS	1	2	3	4	5	6	7	8	9	10
CALL														
ELEV														
WIND														
	SS	SS	SS	SS	11	12	13	14	15	16	17	18	19	20
CALL														
ELEV														

2 MOA TARGET



1400M PROBABILITY OF HIT SHEET

SLANT ANGLE CORRECTION

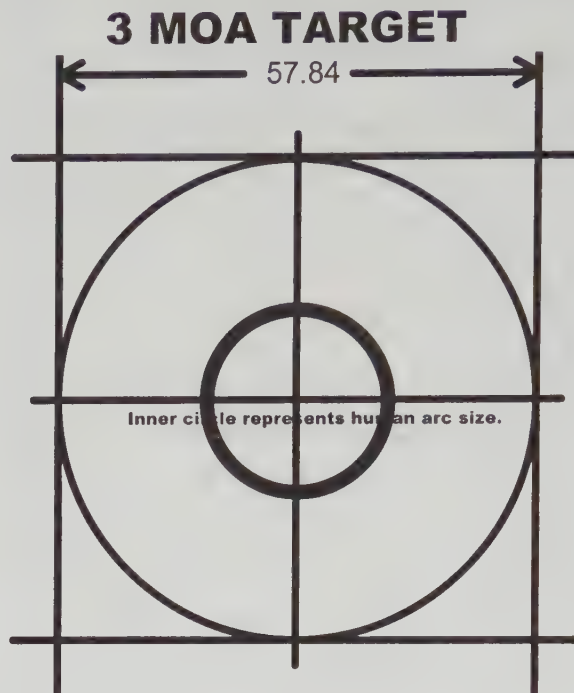
SAC Elevation Setting Correct ELev. Data Used on Gun

BP

TEMP

AMMO
TEMP

	SS	SS	SS	SS	1	2	3	4	5	6	7	8	9	10
CALL														
ELEV														
WIND														
	SS	SS	SS	SS	11	12	13	14	15	16	17	18	19	20
CALL														
ELEV														



1700M PROBABILITY OF HIT SHEET

SLANT ANGLE CORRECTION

SAC Elevation Setting Correct ELev. Data Used on Gun

BP

TEMP

**AMMO
TEMP**

	SS	SS	SS	SS	1	2	3	4	5	6	7	8	9	10
CALL														
ELEV														
WIND														
	SS	SS	SS	SS	11	12	13	14	15	16	17	18	19	20
CALL														
ELEV														

PRECISION ZERO CARD – DAYTIME OPTICS HEAVY RIFLE
WEAPON AND SERIAL NUMBER
OPTICS ON/OFF ZERO CHANGE:

Name:		Location:	
Barometric Pressure:		Air Temperature:	
Ammunition Temperature:		Slant Angle To Target:	
WIND CONDITIONS FROM:		VELOCITY:	
RANGE TO TARGET:			
BASE AMMO TYPE: Example: Mark 211, Mod-0 and Lot #		Mark 211, Mod-0 #123-456-789	
1. REFERENCE ELEVATION SETTING FROM DATA TABLE Example: 13.75 MOA for 500 meters			

USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD ATMOSPHERIC CONDITIONS. *ADD TOTAL OF CHANGES.*

2. TOTAL OF CHANGES FROM MET AND ENV CONDITIONS	+ or -	MOA
---	--------	-----

1. **BULLET DROP COMPENSATORS:** Shoot and adjust Point of Impact to Point of Aim. Slip the BDC ring to the range value for the range you are zeroing the rifle. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.). Re-slip the BDC ring to Range value.
2. **RAW ELEVATION KNOBS $\frac{1}{4}$ or $\frac{1}{2}$ MOA.** Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) Slip elevation knob to the MOA value determined in steps 1 and 2.

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API			
M-20 API-T			
M-33 Ball			
M-17 Tracer			
M-903 SLAP			

PRECISION ZERO CARD – DAYTIME OPTICS
WEAPON AND SERIAL NUMBER

OPTICS ON/OFF ZERO CHANGE:

Name:		Location:	
Barometric Pressure:		Air Temperature:	
Ammunition Temperature:		Slant Angle To Target:	
WIND CONDITIONS FROM:		VELOCITY:	
RANGE TO TARGET:			
BASE AMMO TYPE: Example: Sierra 168 @ 2600 fps / Lot #			
1. REFERENCE ELEVATION SETTING FROM DATA TABLE Example: 13.75 MOA for 500 meters			
2. TOTAL OF CHANGES FROM MET AND ENV CONDITIONS		+ or - MOA	

USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD ATMOSPHERIC CONDITIONS. *ADD TOTAL OF CHANGES.*

- 1. BULLET DROP COMPENSATORS:** Shoot and adjust Point of Impact to Point of Aim. Slip the BDC ring to the range value for the range you are zeroing the rifle. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.). Re-slip the BDC ring to Range value.
- 2. RAW ELEVATION KNOBS $\frac{1}{4}$ or $\frac{1}{2}$ MOA:** Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) Slip elevation knob to the MOA value determined in steps 1 and 2.

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:

ZERO CARD – SIMRAD NIGHT OPTICS

ZERO CARD – SIMRAD NIGHT OPTICS HEAVY RIFLE**WEAPON AND S/N:****NIGHT OPTICS S/N:**

SIGHT CHANGES FROM MOUNTING SIMRAD ON DAY OPTICAL SIGHT	ELEV + or -	WIND L-R	
Name:		Location:	
Barometric Pressure:		Air Temperature:	
% Illumination LUNAR		Cloud/Haze Cover/Obscure	
Ammunition Temperature:		Slant Angle To Target:	
WIND FROM:		VELOCITY:	
RANGE TO TARGET:			
BASE AMMO TYPE: Example: Mark 211, Mod-0 and Lot#			
1. REFERENCE ELEVATION SETTING FROM DATA TABLE Example: 9.50 MOA for 300 Meters			
2. TOTAL OF CHANGES FROM MET AND ENV CONDITIONS		+ or - MOA	

USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM SAC. **ADD TOTAL OF CHANGES.**

- 1. BULLET DROP COMPENSATORS:** Shoot and adjust Point of Impact to Point of Aim. Slip the BDC ring to the range value for the range you are zeroing the rifle. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.). Re-slip the BDC ring to Range value.
- 2. RAW ELEVATION KNOBS $\frac{1}{4}$ or $\frac{1}{2}$ MOA.** Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) Slip elevation knob to the MOA value determined in steps **1 and 2.**

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API			
M-33 BALL			
M-20 API-T			
M-903 SLAP			

THE COMPLETE .50-CALIBER SNIPER COURSE

ZERO CARD – DEDICATED NIGHT OPTICS; HEAVY RIFLES

STAND ALONE NIGHT SIGHTS – EX. AN/PVS-4, AN/PVS-2

WEAPON AND S/N:

TYPE NIGHT AND OPTICS S/N:

MAXIMUM EXPECTED ZERO REPEATABILITY ON/OFF OF NIGHT SITE		ELEV + or -	WIND L-R
Name:		Location:	
Barometric Pressure:		Air Temperature:	
% Illumination LUNAR		Cloud/Haze Cover/Obscure	
Ammunition Temperature:		Slant Angle To Target:	
WIND FROM:		VELOCITY:	
BASE AMMO TYPE: Example: M-118 and Lot #			

ZERO DATA

ZERO RANGE:

For NVDs without trajectory compensation capability, use a "Reverse Image Zero".

--

CORRECTIONS FOR MET AND ENV CONDITIONS

USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD ATMOSPHERIC CONDITIONS. *ADD TOTAL OF CHANGES.*

TOTAL OF CHANGES FROM MET AND ENV CONDITIONS	+ or -	MOA
---	---------------	------------

ADJUSTING ELEV AND WIND KNOBS ON NIGHT SIGHT. Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) Add or subtract any changes based on MET and ENV on the night sight.

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:
M-8 API			
M-20 API-T			
M-33 BALL			
M-17 TRACER			
M-903 SLAP			

WEAPON AND S/N:		NIGHT OPTICS S/N:	
SIGHT CHANGES FROM MOUNTING SIMRAD ON DAY OPTICAL SIGHT	ELEV + or -	WIND L-R	
Name:		Location:	
Barometric Pressure:		Air Temperature:	
% Illumination LUNAR		Cloud/Haze Cover/Obscure	
Ammunition Temperature:		Slant Angle To Target:	
WIND FROM:		VELOCITY:	
RANGE TO TARGET:			
BASE AMMO TYPE: Example: Black Hills 175 and Lot#			
1. REFERENCE ELEVATION SETTING FROM DATA TABLE Example: 9.50 MOA for 300 Meters			
USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD ATMOSPHERIC CONDITIONS. <i>ADD TOTAL OF CHANGES.</i>			
2. TOTAL OF CHANGES FROM MET AND ENV CONDITIONS		+ or - MOA	

1. **BULLET DROP COMPENSATORS:** Shoot and adjust Point of Impact to Point of Aim. Slip the BDC ring to the range value for the range you are zeroing the rifle. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.). Re-slip the BDC ring to Range value.
2. **RAW ELEVATION KNOBS $\frac{1}{4}$ or $\frac{1}{2}$ MOA.** Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) Slip elevation knob to the MOA value determined in steps 1 and 2.

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:

ZERO CARD – DEDICATED NIGHT OPTICS

STAND ALONE NIGHT SIGHTS – EX. AN/PVS-4, AN/PVS-2

THE COMPLETE .50-CALIBER SNIPER COURSE

WEAPON AND S/N: TYPE NIGHT AND OPTICS S/N:

MAXIMUM EXPECTED ZERO REPEATABILITY ON/OFF OF NIGHT SITE	ELEV + or -	WIND L-R	
Name:		Location:	
Barometric Pressure:		Air Temperature:	
% Illumination LUNAR		Cloud/Haze Cover/Obscure	
Ammunition Temperature:		Slant Angle To Target:	
WIND FROM:		VELOCITY:	
BASE AMMO TYPE: Example: M-118 and Lot #			

ZERO DATA

ZERO RANGE: For NVDs without trajectory compensation capability, use a "Reverse Image Zero".	
--	--

CORRECTIONS FOR MET AND ENV CONDITIONS

USE THE CALCULATIONS CARD AND DETERMINE THE CHANGES FOR ENV AND MET CONDITIONS FROM STANDARD ATMOSPHERIC CONDITIONS. *ADD TOTAL OF CHANGES.*

TOTAL OF CHANGES FROM MET AND ENV CONDITIONS	+ or -	MOA
---	--------	-----

ADJUSTING ELEV AND WIND KNOBS ON NIGHT SIGHT. Shoot and adjust Point of Impact to Point of Aim. Add or subtract the total of changes from MET and ENV conditions (2.) from the reference elevation (1.) **Add or subtract any changes based on MET and ENV on the night sight.**

ZERO DEVIATIONS FOR OTHER AMMUNITION

TYPE ROUND	+ or -Elevation	L or R Windage	NOTES:

INITIAL RANGE TO TARGET =
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TYPE AMMUNITION TO USE =

CORRECTIONS FOR SLANT ANGLE TO TARGET

ALTITUDE OF GUN =

ALTITUDE OF TARGET =

DIFF. OF ELEVATIONS (METERS) =
2 Methods of Slant Range Determination

1. COS Angle to TGT X True Range
= Slant Range to TGT

2. $\frac{VD}{HD}$ "ATAN" "COS" X ORIGINAL TRUE RANGE
RESULT IS THE SLANT RANGE

SLANT RANGE CORR. FACTOR

CORRECTED SLANT FIRING RANGE

INITIAL ELEVATION (MOA) TRUE RANGE

ALL MET. CORRECTIONS ARE BASED ON THIS RANGE

ELEVATION SETTING FOR SLANT RANGE

INDEX THIS SETTING ON THE SCOPE (MOA)

CORRECTIONS FOR BAROMETRIC PRESSURE

BP UP – MULTIPLY/// BP DOWN – DIVIDE BY CONSTANT

Standard BP = 29.53 In. Hg.

- INSERT TRUE RANGE ELEVATION DATA
- MEASURED BAROMETRIC PRESSURE OR
USE THE STANDARD FOR THAT ALTITUDE =
- BP CORRECTION FACTOR FROM TABLES =
- SUBTRACT THE *MEASURED* BP FROM 29.53
AND ENTER THIS NUMBER HERE. i.e. 4.10 =
- T-range Setting ÷ Constant (yx key) = NEW
MOA ELEVATION SETTING ON SIGHT
- THIS BOX IS THE + OR – ELEVATION
CORRECTION TO PLACE ON THE SIGHT'S
TRUE RANGE SETTING.

TRUE RANGE ELEVATION
SETTING CORRECTED FOR BP

+ OR – MOA TO APPLY TO THE
ELEVATION SETTING

CORRECTIONS FOR AMBIENT AIR TEMPERATURE
 TEMP UP – DIVIDE /// TEMP DOWN – MULTIPLY BY CONSTANT

Standard AIR TEMP = 50° F.

- INSERT TRUE RANGE ELEVATION DATA
- © 1999
- MEASURED AMBIENT AIR TEMPERATURE OR USE THE STANDARD FOR THAT ALTITUDE =
- TEMP CORRECTION FACTOR FROM TABLES
- SUBTRACT THE *MEASURED* TEMP FROM 59 AND ENTER THIS NUMBER HERE. =
- T-range Setting + Constant (yx key) = NEW MOA ELEVATION SETTING ON SIGHT
- THIS BOX IS THE + OR – ELEVATION CORRECTION TO PLACE ON THE SIGHT'S TRUE RANGE SETTING.

TRUE RANGE ELEVATION SETTING
 CORRECTED FOR AIR TEMP

+ OR – MOA TO APPLY TO THE
 ELEVATION SETTING

TRUE RANGE
 ELEVATION

CALCULATE ALL CORRECTIONS
 FOR MET AND ENV FROM THE TRUE
 RANGE SETTING.

CONSTANTLY RE-CALCULATE TO
 COMPENSATE FOR THE CHANGES IN
 CONDITIONS.

NOTE: THIS SETTING ONLY GOES
 ON THE SCOPE INITIALLY, WHEN
 THERE IS *NO SLANT ANGLE TO THE*

AMMO TEMP =

SLANT RANGE
 ELEVATION

THE SLANT ANGLE ELEVATION
 SETTING IS THE FIRST SETTING
 THAT GOES ON THE SCOPE.

ALL CORRECTIONS FOR MET AND
 ENV ARE DIALED INTO THIS
 SETTING.

—or— MOA FOR BP

—or— MOA FOR AIR

MOA ↗ FOR AMMO
 TEMPERATURE

TOTAL OF ALL CORRECTIONS TO PLACE
 AGAINST THE TRUE OR SLANT = RANGE
 ELEVATION SETTING.

This is a total of changes for BP, AMBIENT AIR TEMP
 and AMMO TEMP.

FINAL SETTING ON THE SCOPE. This is the exact
 final setting. i.e. "7" + 3 MOA or +48.50 MOA.

- RIFLE TWIST CORRECTION =

- DOMINANT WIND CORRECTION (MOA) =
© 1999
- WINDAGE CORRECTION FACTOR =
- Mk211 = 1.02641 M33/M8 = 1.02643
M20 APIT = 1.02869 M903 = U/A
- SUBTRACT THE *MEASURED* TEMP FROM 59
AND ENTER THIS NUMBER HERE. i.e. 2.10 =
- Winds MOA +or x Corr. Factor (yx key) =

FINAL TARGETING DATA

- POINT BLANK ZERO DIAMETER SIZE
(VELOCITY - 1125 FPS AT SEA LEVEL)
- SUPERSONIC BURNOUT OF AMMO
- ENTER THE FINAL CORRECTION
ELEVATION SETTING IN MOA FROM
PAGE 2.

IF ALL CORRECTIONS RESULT IN -MOA ON THE SIGHT, THIS IS CALLED A "GAIN RANGE" SITUATION. THIS MEANS THAT YOUR SUPERSONIC BULLET RANGE IS FURTHER THAN UNDER S.A.C. THE NEXT STEP IS TO DETERMINE THE RANGE AT WHICH THE BULLET WILL GO SUB-SONIC.

TO DETERMINE THE CALCULATED SUPERSONIC BURNOUT RANGE, ADD OR SUBTRACT THE TOTAL OF ALL CORRECTIONS FROM THE *TRUE RANGE* ELEVATION SETTING. INTERPOLATE THE RANGE THAT CORRESPONDS TO THE SOLUTION OF THIS CALCULATION. THAT RANGE IS THE SUPERSONIC BURNOUT RANGE OF THE BULLET. IF YOU ARE CLOSER THAN THIS RANGE, YOU ARE GOOD TO SHOOT, IF NOT MOVE CLOSER OR WAIT FOR FAVORABLE CONDITIONS.

EXAMPLE: TRUE RANGE SETTING = 79.25 MOA
SLANT RANGE SETTING = 76.25 MOA
TOTAL OF ALL CORRECTIONS = -18.25 MOA CORRECTION

FINAL ELEVATION SETTING AFTER CORRECTIONS = +58.00 MOA
CORRESPONDING RANGE TO 58.00 MOA = 1302.56 METERS

THIS RANGE IS UNDER THE S.A.C. BURNOUT RANGE OF THE BULLET. NOW DETERMINE THE ACTUAL RANGE AT WHICH THE BULLET GOES SUBSONIC.

TRUE RANGE SETTING = 79.25 MOA
TOTAL OF ALL CORRECTIONS = -18.25 MOA / ADD THIS TO 79.25 MOA = 97.25 MOA

CORRESPONDING RANGE TO 97.25 MOA = 1672.73 METERS TO SUPERSONIC BURNOUT.

RE-CALCULATED ENGAGEMENT
RANGE AFTER +- BP, TEMP. CORR.

SUPER-SONIC BURNOUT RANGE OF
BULLET AFTER CALCULATIONS

METHOD OF INTERPOLATION

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Interpolation is used to determine the value of a number that falls somewhere between the values of two known numbers:

EXAMPLE: What is the come-up for 658 meters for M118 SB?

1. Start with the known come-ups for a range nearer and farther than 658 meters.

Come up for 600 meters =

23.50 MOA

Come up for 700 meters =

29.75 MOA

2. First, subtract the smaller value from the larger value

29.75 MOA
~~-23.50 MOA~~
3. The result of this is the number of minutes from 600 to 700 meters.

6.25 MOA

We are trying to find the value of the MOA come-up for 658 meters.

4. Drop the digit in the "hundreds" ("6"58) position and multiply X the number of minutes between 600 and 700 meters. Put a decimal point in front of the number as this is the decimal value of the distance you are trying to find.

$$\begin{array}{r} 6.25 \text{ MOA} \\ \times .58 \\ \hline 3.625000 \end{array}$$

5. At this point, the result (3.62500) is added to the "LOW" MOA value.

23.50 MOA

+3.62500

6. Result is the total MOA elevation or simply put:

27.12500 MOA

Put "6" on the scope ring and add 4 MOA. (Round up from 3.62500)

THIS METHOD CAN BE APPLIED TO ANY SITUATION WHERE THE VALUE OF THE NUMBER TO INTERPOLATE IS GETTING LARGER THAN THE SHORT RANGE NUMBER. BELOW IS THE METHOD TO USE WHEN THE VALUES TO FIND ARE "DECREASING" WITH CORRODING INCREASES IN THE BASE VALUES.

This same method is used for interpolating the values of correction constants for uneven ranges. I.E. the constant for temperature; when the range is 777 meters (1.01026), or the constant for barometric pressure when the range is 811 (1.02327) meters.

METHOD OF INTERPOLATION FOR DECREASING VALUES

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This method is used where the value to be interpolated is actually decreasing with increases in the base line values. The example to use is the interpolation of a slant range correction value.

EXAMPLE: What is the correction factor for a target that is at 800 meters (lased range), and is 300 meters below the gun position. Using the formula for percent of slope, it is calculated that the slant angle is 37.5 % of slope.

Referring to the slant range firing table, we see that the only available factors are listed at 30 and 40 degrees.

- 1. Start with the known correction factors for the above and below % values.**

Correction for 30% =	.96
----------------------	-----

Correction for 40% =	.94
----------------------	-----

- 2. We need to know the value of 37.5 %.**

3. Subtract the lower value from the higher value. .96
- .94

4. The results is the factor value difference from 30 to 40 percent of slope. .02

We are trying to find the correction factor for 37.5%.

5. Drop the digit in the “tens” (“3”7.5) position and multiply times the number obtained in the step above (“.02”). (The difference between the factors for 30 and 40 %).

$$\begin{array}{r} 7.5 \\ \times \underline{.02} \\ \hline \end{array}$$

6. The answer is the 1st step in a two step process. = .15000
Result is then divided by "10" because there are 10 increments from 30 to 40 percent. This is also done by moving the decimal place 1 place to the left. = .01500

7. This answer (.01500) is then subtracted from the higher correction factor value.
- | |
|----------|
| .96000 |
| - .01500 |

8. Result is the true correction factor for 37.5%. =.94500

- 9. This number is then multiplied against the true range to obtain the slant range due to gravity.**

THEODOLITE RANGE FINDING

It is important to note that when obtaining a deflection on a target that is not 90 deg. to the position of the station, there will be an error in the range. In this case "Vertical Angular Deflection" will provide the best solution. © 1999

(Size of Target in Meters) X SIN of Angle B (Big Angle)

SIN of Angle C (Small Angle, the deflection)

VERTICAL ANGULAR DEFLECTION w/ Slant Angle to Target

1. The vertical scale on theodolites cannot be "zeroed".

2. Pickup the bottom of the target to be ranged and enter the reading.

3. Slew the reticle to the top of the target to be range and enter:

4. Take a mid-point reading for your slant range

5. Convert the first reading (1.) to decimal format:

6. Convert the second reading (2.) to decimal format:

7. Subtract smaller deflection from the larger deflection.

6. Leave in decimal format and press the SIN key. Enter here.

CONTINUE WITH STEP 8 IF THERE IS SLANT ANGLE INVOLVED IN ANGLE

C

8. Correct Angle C for Slant Angle Optical Error.

- Enter > Angle C Reading =
- Divide by
- Enter > Angle to Target in Deg. Min. Sec.
- COS key
- = Corrected Angle C Reading
- Hit COS key and enter this value on Page 1 of
- The CALCFORM in Slant Range Correction Factor

9. - Enter "90" on the calculator

- Hit the (-) key
- Enter the actual deflection converted to decimal format. (i.e. .10° 22") to (.17278)
- Hit the (=) key
- This is the Angle B in decimal format.
- - Hit the (SIN) key and enter in the box

10. Enter the size of the target in METERS

8

11. EXECUTE THE FORMULA

Data in Box 8.

Data in Box 7.

X

DIVIDE BY

Data in Box 6

11. RANGE TO TARGET =

THEODOLITE RANGE FINDING

© 1999

(Size of Target in Meters) X SIN of Angle B (Big Angle)

SIN of Angle C (Small Angle, the deflection)

HORIZONTAL ANGULAR DEFLECTION

1. Zero the horizontal scale on the Optical Micrometer.
2. Unlock the locks on the Optical Micrometer so that when you turn the turret head the scale on the micrometer will not move from "zero".
3. Fine tune the reticle to the left side of the target to be range.

4. Lock in the optical micrometer.

5. Slew the reticle to the right side of the target and enter the deflection.

Angle C Deflection

6. Enter the Angle C (Step 5 above) in the calculator and convert to decimal format and press SIN.

SIN Ang. C=

6

7. - Enter "90" on the calculator

- Hit the (-) key
- Enter the actual deflection converted to decimal format. (i.e. .10' 22") to (.17278)
- Hit the (=) key
- This is the Angle B in decimal format.
- Hit the (SIN) key and enter in the box

SIN Ang. B=

7

8. Enter the size of the target in METERS

8

9. EXECUTE THE FORMULA

Data in Box 8.

Data in Box 7.

X

DIVIDE BY

Data in Box 6

10. RANGE TO TARGET =

THEODOLITE RANGE FINDING

(Size of Target in Meters) X SIN of Angle B (Big Angle)

SIN of Angle C (Small Angle, the deflection)

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ANGLE B METHOD OF HORIZONTAL ANGLE DEFLECTION

1. Locate the Theodolite at Point A on the Range triangle. This is the primary gun position.
2. Unlock the locks on the Optical Micrometer so that when you turn the turret head the scale on the micrometer will not move from "zero".
3. Fine-tune the reticle to the target to be down range point that represents Point C and lock in the optical micrometer.
4. Slew the reticle to the right or left until you get a deflection of 90 Degrees from the AC line and set a stake at Point B the desired baseline measurement away from Point A. (30 meters)
5. Slew the theodolite back to Point C and you should get a 0 reading. Recheck your angle to Point C, confirm 90 degrees. Return head to "0" reading and lock in the micrometer.
6. Move theodolite to Point B on the triangle, level and obtain Point A in the reticle. Unlock the micrometer, slew the head from Point A to Point C, and note the deflection. 6
7. Enter the Angle C (Step 5 above) in the calculator 7
8. and convert to decimal format and press SIN. 8
9. Repeating Measurements? 9
10. Average of Repeating Measurements Angle B Average
11. - Enter "90" on the calculator
12. Hit the (-) key
13. Enter the actual deflection converted to decimal format. (i.e. .88 Deg 15") to (88.25)
14. Hit the (=) key
15. This is the Angle C in decimal format. 7
- Hit the (SIN) key and enter in the box
16. 8. Enter the size of the target in METERS 8
17. EXECUTE THE FORMULA

Data in Box 8.		Data in Box 7.		
	X			
DIVIDE BY				

10. RANGE TO TARGET =

ADDITIONAL NOTES ON THEODOLITE RANGE FINDING

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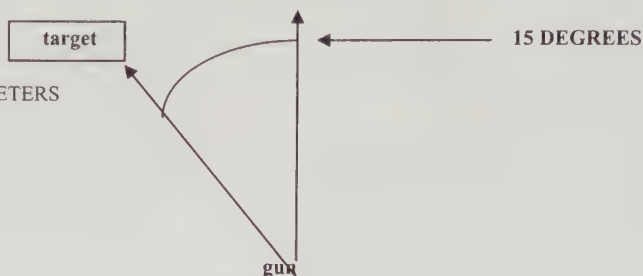
** TARGETS NOT ON A 90 DEGREE ANGEL TO THE STATION

1. You get more accurate range when the target to be ranged is 90 degrees from the theodolite station. This is not always possible. Use the following technique.

- a. Estimate the angle that the target is from your position.

BOX REPRESENTS
A MISSLE THAT IS
NOT 90 DEGREES TO
THE GUN TEAM

TARGET IS 10 METERS
LONG.



- b. Use the same formula for slant range correction.
- c. COS of the offset angle X the size of the target in meters.
- d. This corrects the size of the target to the new apparent size due to the angular offset.

EXAMPLE ABOVE: $15 (\text{COS}) = .96593 \times 10 \text{ METERS}$

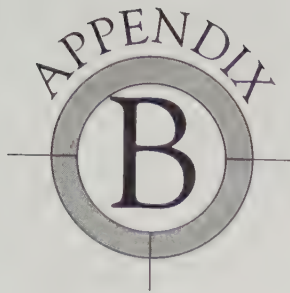
$= 9.65926 \text{ METERS (NEW SIZE)}$

Deflection of : 25' 15" // 10 Meter Target // Range = 1361.45 Meters

Target Corrected to 9.65926 meters // Range = 1315.06 Meters

THIS IS SIGNIFICANT ERROR. THE APPARENT TARGET SIZE MUST BE

CORRECTED FOR IF POSSIBLE. THE ABOVE SITUATION WOULD HAVE RESULTED IN A MISS.



HTI Program of Instruction

PROGRAM OF INSTRUCTION

FOR

SPECIAL OPERATIONS HARD TARGET INTERDICTION COURSE

THIS IS A PEACETIME AND MOBILIZATION POI

LENGTH: PEACETIME: 2 WEEKS

MOBILIZATION: 2 WEEKS

Approved by:

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PREFACE

COURSE TITLE: HARD TARGET INTERDICTION

TRAINING LOCATION: TBD

PURPOSE: To train selected personnel in the transition from light to heavy sniper rifles. Personnel will receive training; basic and advanced long-range sniping techniques.

SCOPE: Sniper personnel selected for training will receive transitional training on the selected .50 caliber Sniper Weapons System. They will receive training on the 4-man sniper team concept and the Hard Target Interdiction program as it exists. Snipers will receive advanced sniper techniques training that is not currently taught at any US school. All personnel will understand the functioning of the .50 SWS and the concepts involved in Hard Target Interdiction.

PREREQUISITES: Desired graduate of SOTIC Level I, Level II administered by 1st SFG(A) that included Hard Target Interdiction Training and a member of SOF unit.

SPECIAL INFORMATION: NONE

SECURITY CLEARANCE: SECRET

POI FILE INDEX. Training Annexes:

<u>FILE NUMBER</u>	<u>CLASSROOM SUBJECTS</u>	<u>HOURS</u>
HTI001	Introduction to Hard Target Interdiction	0.5
HTI002	Mission Familiarization	2.0
HTI003	Introduction to the .50 cal. SWS	2.0
HTI004	Sight Adjustment and Zeroing	1.5
HTI005	Introduction to Night Vision Devices	1.0
HTI006	Selection of Ammunition (Availability) (Internal Ballistics)	2.0
HTI007	Introduction to Firing Tables and Their Uses (Exterior Ballistics)	3.0
HTI008	Exterior Ballistics, Primary Functions	2.0
HTI009	Exterior Ballistics, Secondary Function	2.0
HTI010	Correcting for Meteorological Conditions	4.0
HTI011	Effects of Wind and Corrections	2.0
HTI012	Application of Fire	4.0
HTI013	Range Estimation Methods	2.0
HTI014	Target Analysis	3.0
HTI015	Tactical Concepts	3.0
HTI016	Rig the SASR for Infiltration	2.0

RANGE SCENARIOS

HTI PROGRAM OF INSTRUCTION

HTI017	Zero Telescopic Sights	4.0
HTI018	.50 Caliber Marksmanship - 600 meters	4.0
HTI019	.50 Caliber Marksmanship - 1000 meters	6.0
HTI020	.50 Caliber Marksmanship - 1300 meters	6.0
HTI021	.50 Caliber Marksmanship - 1500 meters	4.0
HTI022	Integrated Fire Procedures - 1200 meters	4.0
HTI023	Field Shoot I	5.0
HTI024	Field Shoot II	4.0
HTI025	Field Shoot III	4.0
HTI026	Field Shoot IV (Night Fire)	4.0
HTI027	Known Distance .50 Cal. Match	6.0

EXAMINATIONS

00X1	HTI Written Examination	5.0
00X2	Field Shoot V (Field Fire Exam)	5.0

TRAINING ANNEXES

ANNEX A: HARD TARGET INTERDICTION CLASSROOM SUBJECTS

PURPOSE: To prepare selected personnel in the basics of the .50 cal. SWS and prepare them for the advanced techniques involved in HTI training.

POI FILE	TITLE	HOURS
----------	-------	-------

HTI001	Introduction to Hard Target Interdiction	0.5
--------	--	-----

SCOPE: The student will be introduced to the Hard Target Interdiction program. He will be briefly introduced to all the weapons and equipment he will encounter throughout the course. A safety briefing will be presented at this time.

REFERENCES: .50 Caliber Firing Data Book

HTI002	Mission Familiarization	2.0
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SCOPE: The student will be presented an overview of a Hard Target Interdiction team. A brief history of the subject will be discussed to cover the background of the training. Training will include training on target analysis as it applies to the HTI mission. HTI operational concepts and methods will also be instructed.

REFERENCES: Hard Target Interdiction Operational Concept, History of Modern US Sniping

HTI003	Introduction to the .50 Caliber Sniper Weapons System	2.0
--------	---	-----

SCOPE: The student will be technically introduced to all of the current .50 Caliber SWS. He will receive instruction on its field stripping, cleaning, maintenance, and peculiarities. A safety briefing will accompany this class.

REFERENCES: NONE

HTI004 Sight Adjustment and Zeroing 1.5

SCOPE: The student will receive instruction on the use of all available optical systems. This will include instruction on the proper zero techniques to use. Instruction will be provided on the use on any iron sight capabilities that may be used on the Barrett SWS.

REFERENCES: All applicable Operator's Manuals on the .50
Caliber SWS.

HTI005 Introduction to Night Vision Devices 1.0

SCOPE: Instruction will be presented on the night vision device selected for use on the .50 Cal. Barrett SWS. Instruction will be provided on any other NVD including: AN/TVS-4, AN/PVS-4 and the SIMRAD systems. The capabilities and limitations will be addressed. Also special peculiarities that are noted on each system will be covered. Details on the class include the value of different reticles and how to adopt these reticles for use on the .50 Caliber SWS.

REFERENCES: TC 24-14 and FMFM 1-3B

HTI006 Selection of Ammunition (Availability) 2.0
(Internal Ballistics)

SCOPE: Instruction will be provided on the different types of ammunition available for use in the .50 Caliber SWS. Different types of standard ammunition and NSN/DODIC numbers will be provided for all types of ammunition. In this instruction; the capabilities, limitations, and the best ammunition to select based on its ballistics performance will be covered. Instruction will be provided on the gains or losses in ballistic performance based on altitude above sea level. A safety briefing will be presented in this class based on the types of ammunition that will be used in this class.

REFERENCES: TBP

HTI007 Introduction to the Firing Tables 3.0
and Their Uses

SCOPE: The student will be introduced to the .50 Cal. firing data book. this manual is the data that allows the sniper to place accurate fire on the target. They will receive data that contains primary function and secondary function data. Tactical characteristics of ammunition are listed here. Hard data on correcting for meteorological condition and terrain considerations is listed in

this book.

REFERENCES: .50 Caliber Firing Data Book

HTI008	Exterior Ballistics, Primary Functions	2.0
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SCOPE: The student will be instructed on the primary functions as they are addressed in the data firing books. They will be shown how to use and apply the data that is located in the book. Instruction will be provided as how to use these books a mission-planning tool. The instruction will begin on a basic level. Men of today's snipers are not trained at a basic level on the external ballistics aspects of long range shooting. This period of instruction will provide them with the basic knowledge to effectively employ their shooting data books.

REFERENCES: .50 Caliber Firing Data Book, Ingall's Artillery Circular "M", and Naval Gunnery Textbook, dated 1917.

HTI009	Exterior Ballistics, Secondary Functions	2.0
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SCOPE: Students will be instructed on the secondary functions as they are addressed in the data firing books. They will be shown how to use and apply the data that is located in the book. These secondary functions mainly are used as a mission planning aid. they contain information such as the flight times of ammunition, fall angles, corrections for spinning drift, and maximum ordinate data. This information will further their knowledge in exterior ballistics. Classes in exterior ballistics also increase the shooter confidence that he is fully knowledgeable of what his weapon and ammunition is doing.

REFERENCES: .50 Cal. Firing Book, Ingall's Artillery

HTI010	Correcting for Meteorological Conditions	4.0
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SCOPE: Students will receive detailed instruction on how to correct for all meteorological conditions as they affect the flight of the ammunition. They will be taught how to make pre-firing corrections for elevation based on the altitude of the firing position above sea level, ambient air temperature, hard target team can place the first shot on a target without corrections for weather after the shot. Shooting at extreme ranges is made more difficult by variations in the atmosphere from the accepted standard shooting conditions. These corrections are done in simple math so that the need of a calculator makes them faster, yet they can be done with pencil and paper.

HTI011 Effects of Wind and Corrections 2.0

SCOPE: Students will receive a refresher course in reading winds and correcting for winds. Another factor that which is usually not taught in lower level courses is the corrections for wind; based on ambient air temperature. At extreme shooting ranges the ambient air temperature has an impact additional instruction will be provided on the methodology involved in wind predicting. Methods of correcting for crosswind angles and conversion to true wind values will be addressed at how much a certain air velocity moves the bullet crossrange as it flies down range.

REFERENCES: .50 Cal. Firing Data Book, Sierra Reloading Manual.

HTI012 Application of Fire 4.0

SCOPE: Students will receive instruction in the application of fire of material learned in previous classes. At this point the tactical aspects of the firing comes into play. Instruction will be provided in the elevation corrections necessary when firing uphill and downhill (slant range firing). Students will receive instruction in the use of Point Blank Zero firing techniques as a method of quick engagement of targets of opportunity where a deliberate fire mission is not possible. this portion also integrates in the range estimation as the use of the Danger Space tables that are used. This further involves mission planning methods. During this class the hard target teams will learn their procedures for setting the shot; step by step.

REFERENCES: Special Operations Target Interdiction Course lesson outline on Application of Fire, .50 Cal. Firing Data Book, Artillery Circular "M", and The Rifleman Went to War.

HTI013 Range Estimation 2.0

SCOPE: Students will receive instruction of the methodology of range estimation. The use of laser range finders, mil relation, triangulation, and the integrated use of Danger Space tables will be incorporated in this class. An introduction to special equipment and their functions is the presented.

REFERENCES: SOTIC lesson outline on Range Estimation.

HTI016 Rigging the SASR for Infiltration 2.0

SCOPE: The nature of this training is to prepare the SASR and HTI particular team equipment for infiltration in the area of operations. Methods of rigging for both static line and military freefall will be provided. Methods of preparing the SASR and related equipment for waterborne

HTI020 .50 Caliber Marksmanship -- 6.0
 1300 meters (pair firing)

SCOPE: Students will pair fire on a known distance at a range of 1300 meters. This is a grouping exercise. At this point the only meteorological conditions that the students will correct for is the wind conditions. Their instructors will give all other meteorological condition corrections to them.

REFERENCES: TBP

HTI021 .50 Caliber Marksmanship -- 4.0

SCOPE: Students will pair fire on a known distance at a range of 1500 meters. This is a grouping exercise. At this point the only meteorological conditions that the students will correct for is the wind conditions. Their instructors will give all other meteorological condition corrections to them.

REFERENCES: TBP

HTI022 Integrated Fire Procedures -- 4.0
 1200 meters (4 man teams)

SCOPE: This is the first time the students will fire in 4 man teams. Initially they will operate with two shooters working with one observer. They will then move the three shooters with one observer. They will then move to three shooters with one observer calling corrections for all three guns. This will demonstrate the flexibility and firepower of the 4 man concept. This exercise does much to build the confidence of the shooters. This is the initial exposure to the stepped firing sequence. At this point the teams will make all meteorological corrections.

REFERENCES: TBP

HTI023 Field Shoot I 5.0

SCOPE: This phase of the training will incorporate shooting and classroom techniques. They will operate in their 4 man teams. Engagement range will be unknown with a maximum of 600 meters for the targets. There will be one SWS per firing team with one observer and two security personnel. Each shooter will engage two targets. All corrections for meteorological and terrain will be made in this scenario. There will be eight firing engagements.

REFERENCES: NONE

HTI024 Field Shoot II 4.0

SCOPE: This phase of field shooting will be on targets of unknown distance up to a range of 1200 meters. The hard target teams will have 2 SWS to engage targets with. They will be required to use simultaneous fire one observer calling corrections and commands. Each firing pair will engage the same target with simultaneous fire and each pair will engage two targets. A rotation will be used every two engagements. There will be 8 firing engagements.

REFERENCES: NONE

HTI025 Field Shoot III 4.0

SCOPE: The final phase of field shooting will incorporate all instructed methods of target engagement. The maximum firing range will be 1500 meters. The firing teams will be employing three SWS and observer. Simultaneous fire on a single target is the directive. Each firing team will engage 8 targets.

REFERENCES: NONE

HTI026 Field Shoot IV (Night Fire) 4.0

SCOPE: This is the night fire portion of the HTI course. The maximum firing range will be 1000 meters. The firing teams will be employing three SWS and observer. Simultaneous fire on a single target is the directive. Each firing team will engage 8 targets.

REFERENCES: NONE

HTI027 Known Distance Match .50 Cal. Rifle 5.0

SCOPE: This is a long range match at 600, 1000, and 1300 meters. Targets will be the NRA 600 and 1000 yd. bull targets. Format will be based on a 4 man team firing one man at a time in a time limit for the 4 man team.

REFERENCES: NONE

00x2 Field Shoot IV -- Field Shoot Examination 5.0

SCOPE: This is a field shoot examination. Each firing team will have 2 hours in which to plan their fire mission. They will be presented a target and a field of fire. The firing teams may select the number of weapons they feel they will need to complete the mission.

EXAMINATION ANNEX

COURSE: HARD TARGET INTERDICTION

EVALUATION IDENTIFICATION	ACADEMIC ANNEX	SCOPE/POI FILE NO.	HOURS
00X1	A	HTI002/HTI003/HTI004 HTI005/HTI006/HTI007 HTI008/HTI009/HTI010 HTI011/HTI012/HTI013 HTI014/HTI015	5.0
00X2	B	HTI017/HTI018/HTI019 HTI020/HTI021/HTI022 HTI023/HTI024/HTI025	5.0

HTI PROGRAM OF INSTRUCTION

TASK AND SUBJECT SUMMARY

COURSE: HARD TARGET INTERDICTION

1. PROPONENT APPROVED TASKS FOR RESIDENT SOTIC LEVEL I TRAINING, FBNC.
EXTRACTED FROM USAJFKSWCS APPROVED SOTIC POI USING SOTIC POI FILE NUMBERS.

<u>TASK NUMBER</u>	<u>TITLE</u>	<u>POI FILE NUMBER</u>
04-9144.01-1001	Draw a panoramic sector sketch	8322/8341/8352/8353 8354/8387
04-9144.01-1002	Fill out and maintain an observer's log	8322/8341/8351/8352 8353/8387
04-9144.01-1003	Determine intracity visibility	8305
04-9144.01-1004	Plan and select a line of advance	8304/8310/8320/8322 8351/8352/8355/8361 8362/8364/8365/8369 8372/8373/8387
04-9144.01-1005	Write a sniper mission plan	8304/8305/8308/8387
04-9144.01-1007	Describe the principles and methods of training snipers	8301/8306
04-9144.01-1008	Describe the uses and roles of special operations snipers in the HTI role	8301/8304/8308
04-9144.02-1000	Inspect, clean, and maintain personal and team optical equipment	8311/8318/8327/8328 8329/8330/8332/8333
<u>TASK NUMBER</u>	<u>TITLE</u>	<u>POI FILE NUMBER</u>
		8335/8338/8341/8351
04-9144.02-1007	Inspect, clean and maintain the SWS	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8389
04-9144.02-1010	Fire the sniper weapon	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389
04-9144.03-1000	Determine distance with the unaided eye	8320/8321/8322/8341 8352/8354/8355/8372 8387
04-9144.03-1001	Determine distance with the mechanical and optical aid	8320/8321/8322/8341 8352/8354/8355/8372 8387
04-9144.03-1003	Apply the four fundamentals of shooting	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389

THE COMPLETE .50-CALIBER SNIPER COURSE

04-9144.03-1005	Determine wind velocity, direction, meteorological conditions, predict, and make sight corrections to compensate for wind and meteorological conditions	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387
<u>TASK NUMBER</u>	<u>TITLE</u>	<u>POI FILE NUMBER</u>
		8388/8389
04-9144.03-1006	Determine point of impact on target by reading bullet trace	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389
04-9144.03-1007	Engage targets at the maximum effective range of the SWS	8312/8313/8314/8315 8327/8333/8341/8387 8389
04-9144.03-1008	Describe the application of rifle fire over uneven ground at unknown distances	8336/8341/8387
04-9144.03-1009	Describe methods of indicating targets	8320/8322/8336/8341 8351/8352/8353/8354 8361/8387
04-9144.03-1010	Determine range by flash bang	8320/8355
04-9144.03-1011	Determine weapon type by sound	8351/8355
04-9144.04-1000	Perform stealth movement methods	8351/8352/8365/8369/ 8372/8373/8387
04-9144.04-1001	Locate the enemy by his fire	8320/8322/8351/8352 8355
04-9144.04-1002	Demonstrate observation techniques and recall of detail	8357/8387
<u>TASK NUMBER</u>	<u>TITLE</u>	<u>POI FILE NUMBER</u>
04-9144.05-1000	Conceal self and equipment	8341/8361/8362/8364 8365/8372/8378/8387
04-9144.05-1002	Construct a ghillie suit	8341/8361/8362/8364 8365/8372/8378/8387
04-9144.05-1003	Construct sniping hides	8304/8305/8351/8352 8353/8354/8361/8362 8378/8379/8387
04-9144.04-1004	Camouflage self and equipment	8304/8305/8351/8352 8353/8354/8361/8362 8378/8379/8387
04-9144.04-1005	Selecting and tailor ammunition	8307
04-9144.06-1001	Demonstrate supported shooting positions	8311/8318/8327/8328 8329/8330/8332/8333

HTI PROGRAM OF INSTRUCTION

		8335/8338/8341/8351 8352/8362/8372/8387 8388/8389
04-9144.06-1002	Adjust and correct iron and telescopic sights	8314/8315/8318/8327 8328/8329/8330/8332 8333/8337/8341/8387 8388/8389
04-9144.06-1003	Engage stationary targets with the SWS	8311/8318/8327/8328
<u>TASK NUMBER</u>	<u>TITLE</u>	<u>POI FILE NUMBER</u>
		8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389
04-9144.06-1004	Engage moving and snap targets with the SWS	8312/8313/8328/8329 8332/8341/8389
04-9144.06-1005	Zero the SWS	8314/8318/8327/8335 8337
04-9144.06-1006	Fill out and maintain a range card	8322/8341/8352/8353 8354/8387
04-9144.06-1007	Engage targets with NVDs	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389
04-9144.06-1007	Engage targets using NVD on the SWS	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389
04-9144.06-1008	Engage targets during times of limited visibility with the telescopic sight	8312/8313/8314/8315 8320/8322/8330/8351

AMMUNITION SUMMARY

COURSE: HARD TARGET INTERDICTION

1. The following is the ammunition requirements for a two week POI for Hard Target Interdiction.
2. Requirements for each man unless otherwise noted.

POI FILE #	NUMBER/TYPE
HTI017	X 20 M-8 API / X 10 M-20 API-T
HTI018	X 30 M-8 API / X 10 M-20 API-T
HTI019	X 30 M-8 API / X 10 M-20 API-T
HTI020	X 30 M-8 API / X 10 M-20 API-T
HTI021	X 30 M-8 API / X 10 M-20 API-T
HTI022	X 25 M-8 API / PER 4 MAN TEAM X 5 M-20 API-T
HTI023	X 30 M-8 API / PER 4 MAN TEAM X 5 M-20 API-T
HTI024	X 30 M-8 API / PER 4 MAN TEAM X 5 M-20 API-T
HTI025	X 30 M-8 API / PER 4 MAN TEAM X 5 M-20 API-T

PER TEAM REQUIREMENT: 115 RDS. M-8 API
20 RDS. M-20 API-T

4. DODIC REQUIREMENTS:

- (a.) Both required types of ammunition are issued in individually packed boxes of 10 rds. ea.

10 round boxes M-8 API DODIC: A532
M-20 API-T DODIC: A542

- (b.) An alternative to individually packaged ammunition is the linked ammunition. The ammunition is the same. It is preferable to use non-linked ammunition because in the manufacturing process, damage can occur due to the linking process.

100 round belts: linked 4:1 M-8/M-20 API/API-T
DODIC: A576

- (c.) The standard military round of ammunition as approved by Rock Island Armory is the Raufoss Green Tip. This is a much more accurate and destructive round of ammunition than is M-8 API. If possible all above ammunition should be replaced with this ammunition.

DODIC: A606 NSN: 13-5-01-250-8162

HTI PROGRAM OF INSTRUCTION

EQUIPMENT SUMMARY

COURSE: HARD TARGET INTERDICTION

<u>LIN/NSN</u>	<u>NOMENCLATURE</u>	<u>POI FILE NUMBER</u>	<u>QUANTITY</u>	<u>REMARKS</u>
B67766	Binoculars, M19, M22	8322/8351/8352/8353 8354/8362/8372/8387	6	Critical
N04732	AN/PVS-4 NVD	8334/8335/8338/8387	24	Critical
	AN/PVS-7B NVD	8334/8335/8338/8387	24	Critical
	SIMRAD NVD	8334/8335/8338/8387	24	Critical
	Radio Set, AN/PRC-119	8318/8322/8327/8328 8329/8330/8332/8333 8335/8337/8338/8341 8352/8362/8372/8387	4	Critical
Y35477	Telescope, M-49 Observation	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	24	Critical
	Rifle, .50 Cal.	8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389		
6545-00-912-9890	Medical Kit, M-5	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	02	Critical
6625-00-x02-3712	Mini-Laser Range Finder	8320/8321/8322/8387	08	Critical
DSA-120-76-AF07	Litter	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	02	Critical
Local Purchase	Burlap Material	8361/8362/8364/8372 8378	48 yards	Critical
Local Purchase	Spotting Scope, 100mm UNERTL	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	06	Critical
	.50 Cal. Cleaning Patch	8311/8318/8327/8328 8329/8330/8332/8333	24,000	Critical

THE COMPLETE .50-CALIBER SNIPER COURSE

		8335/8338/8341/8351 8352/8362/8372/8387 8388/8389		
Local Purchase	1 Pc. Cleaning Rods	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	24	Critical
Local Purchase	Target, NRA 200 yd Bull Army "A"	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	200	Critical
Local Purchase	Target, NRA 600 yd Bull Army "B"	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	200	Critical
Local Purchase	Target, FBI Silhouette	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	300	Critical
Local Purchase	Target, E-Type	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	300	Critical
S-4 Request	Target Sticks, 2 x 2 x 8	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	100	Critical
	M1907 Leather Slings	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387 8388/8389	20	Critical
Local Purchase	Mount, AN/PVS-4 to Leupold Base, M-24 SWS	8311/8318/8327/8328 8329/8330/8332/8333 8335/8338/8341/8351 8352/8362/8372/8387	20	Critical

TRANSPORTATION SUMMARY

COURSE: HARD TARGET INTERDICTION

<u>LIN/DSN</u>	<u>NOMENCLATURE</u>	<u>POI FILE NUMBER</u>	<u>QUANTITY REQUIRED</u>
X40009	Truck, M35A2, 2.5 ton	Entire Course	2
	HUMVV, 1.25 ton	Entire Course	2
	Trailer .75 ton	Entire Course	1

FACILITIES SUMMARY

COURSE: HARD TARGET INTERDICTION

<u>DESCRIPTION AND SCOPE</u>	<u>POI FILE NUMBER</u>	<u>DAYS OF USAGE</u>
General Instruction Bldg.	II001/II002/II003/II004 II005/II007/II008/II009 II010/II011/II012/II013 II014/II015/II016/II018 II019/HTI001/HTI002/HTI0011 HTI0012/HTI0013/HTI0014 HTI0015/HTI0017/HTI0018 HTI0019/HTI0010/HTI004	15
25 Meter Zero Range	R002/R003/R004	3
Known Distance Range	R002/R003/R004/R005 R007/R008/R011/R012 R013	10
Unknown Distance Range	R011/R012/R013	4
Standard Military Training Area	II018/II019/II021/	4
Ammunition Storage Area	Entire Course	15
Arms Room Storage	Entire Course	15



5000 Meter Sniper Rifle Concept

PROPOSAL R&D ON LONG-RANGE SNIPER WEAPONS Los Alamos National Laboratory MEE-3

Recent events have shown that the probability is high that treaties will be signed in the near future, leading to a reduction of nuclear weapons. This will lead to more dependence on conventional weapons. In the future world of terrorists and limited war, the role of the sniper will become increasingly important. The ability to selectively wound or kill at extreme ranges with little risk to one's own personnel can be a very powerful weapon on the battlefield as well as in an anti-terrorist role.

The current state of the art in long-range shooting using highly refined conventional weapons and ammunition has an effective range of 1200 meters. This proposal is for research to extend the effective range up to 5000 meters. To do this, we must combine improvements in weapons technology with modern electronics and computers. It is a sad fact that no significant improvements have been made in small arms since before WWII. Much work has been done in aircraft weapons and anti armor, but the foot soldier is still using a weapon not much different in operation than what his grandfather used in WWII. The cartridge dates back even further--prior to WWI.

BALLISTICS:

In order to make it practical to shoot accurately at these ranges, one of the most important factors is to shorten the time of flight of the projectiles. This has the important effect of lessening the need to anticipate movement of the target and minimizing the effects of wind and gravity. This is accomplished by increasing the average speed of the projectile. There are several ways to do this. One is to increase the starting velocity. Another is to minimize the loss of velocity caused by air friction.

Increasing starting velocity has some practical limitations. As the starting velocity goes up, the recoil of the weapon increases. There is a limit to the amount of recoil which can be tolerated by the operator in a weapon whose weight is within practical limits. Additionally, limits on propellants make it improbable that velocities can get much above 1600m/s using conventional types of ammunition. We are not limiting this proposal to conventional ammunition, but this is a good starting point.

The most promising area for improvement is in decreasing the loss of velocity caused by the projectile's passage through the air. The ballistic coefficient is the measure of the drag on the projectile, as it passes through the air, relative to its weight. Improvements in the ballistic coefficient can be made by lessening the air drag (streamlining) and altering the ratio of mass to diameter (sectional density).

In the past 60 years, projectile shapes have not altered appreciably. The current shapes were determined by much practical testing in the early years of this century. Not much research has been done since WWII. With modern computer analysis and understanding of aerodynamic principles, it should be possible to significantly improve the aerodynamics of a projectile.

Increasing the sectional density can be made in any of several ways. One is to use a more dense material for the projectile. This is one reason for the use of depleted Uranium or tungsten projectiles for some aircraft and naval guns. Another approach is to use larger caliber guns. Browning .50 caliber has been proposed as a long-range sniper weapon. Since the air resistance is proportional to the radius squared of the projectile (frontal area) while mass is proportional to the cube of the radius (for a given shape), increasing the projectile size works, but only up to the point where the recoil becomes impractical. The .50 Browning is beyond this point in a reasonably portable weapon.

Improving the aspect ratio (length/diameter) of the projectile is another way to improve the sectional density. A long slender, projectile has less air resistance than a short, fat one of the same mass and shape. One problem with extreme aspect ratios is the difficulty of spin stabilizing long, slender

projectiles. Conventional projectiles are spun by the rifling in the weapon's bore. The greater the aspect ratio, the faster it has to be spun to achieve stability. At some point, the rifling pitch becomes too steep to spin the projectile.

Another problem is the difficulty of accelerating these projectiles by the conventional means of gas pressure against the base of the projectile. This is the reverse of the effect caused by the air resistance. We are accelerating the projectile by gas pressure against the base and it is slowed by air (a gas) resistance against the nose. If the mass/diameter ratio is large (long and slender), it has a good aspect ratio and low air resistance, but there isn't much area for the gas pressure of the propellant to work against while accelerating the projectile.

Aerodynamically one of the best projectiles currently in use in small arms is a 12.3 gram, .30 caliber boat-tail spitzer. It has a ballistic coefficient of .61. This projectile when fired by a cartridge similar to the 7.62 NATO has an initial velocity of 830m/s. At 1000m, its velocity has dropped to about 300m/s and this is near the practical range for accurate shooting. Preliminary computer analysis shows that a reasonable projectile for use at 5000m should have a ballistic coefficient of about 1.4. Initial velocity should be in the range of 1600m/s. This gives a time of flight of 5.5s to 5000m. The computer analysis shows this is possible by using a combination of improved aerodynamics and a large mass/diameter ratio. The stability problem could be addressed by a combination of spin and aerodynamic stabilization. The acceleration problem is solved by using a carrier or sabot and firing the projectile in a bore that is larger than the projectile.

A possible configuration is a projectile of 6mm in diameter which would be 50mm in length if the material used for the projectile was lead. This would be impractical to spin stabilize and would require aerodynamic stabilization. If the projectile were tungsten or depleted uranium, the length would be about 30mm and it could be spin stabilized. In either case, the projectile would weigh about 12 grams and could be fired at an initial velocity of 1600M/S in a gun with a 7-8mm bore using a sabot. Recoil in a gun of 7kg weight would be about the same as a 7.62mm NATO round in a 4kg service rifle. At 5000m, this projectile would still be traveling at 500m/s.

ABSOLUTE ACCURACY:

It does no good to deliver a projectile at these ranges if you can't hit the intended target. Absolute accuracy is measured in Minutes of Angle (MOA). For an estimate, 1 MOA is about equal to 25mm at 100m. So a weapon with an absolute accuracy of 1 MOA would be able to consistently hit a target 25mm in diameter at 100m or one 250mm in diameter at 1000m. Given that the "disabling zone" of a human is about 300mm X 450mm, the required accuracy to make consistent hits on a human at 5000m is about .3MOA. Good quality conventional, mass-produced weapons with a little attention and selection of ammunition can consistently achieve better than 1MOA. Specialized target weapons under controlled conditions regularly achieve .25MOA. The necessary absolute accuracy is reachable but only with some attention.

Absolute accuracy is a function of many factors. If it were possible to fire identical projectiles at identical velocities from a barrel pointed at exactly the same place, under identical wind conditions, they would impact very close to the same place at any range. This ideal is what must be approached in order to achieve the desired accuracy.

To obtain identical projectiles, manufacturing tolerances must be kept tight. Special attention must be paid to balance because of the requirements for high-speed spin stabilization on these long projectiles. This, along with high standards of quality control, should assure the manufacture of adequately precise projectiles. Production volume need not be very high, so time can be taken to insure quality and consistency.

To achieve velocity stability in chemically propelled weapons, it is necessary to improve the consistency and burning characteristics of the propellant. This will give improvements in consistency and can increase the achievable velocity. An ideal propellant should build up pressure in a controlled manner and maintain this pressure as the projectile travels down the barrel. Much research has been done at Los Alamos in development of explosives with extremely consistent

performance for use in nuclear weapons. This expertise can be applied to the problem of achieving the necessary consistency.

Other means of accelerating projectiles may be feasible and should be studied. Two which should be evaluated are magnetic rail guns and gas guns. Both of these, as well as conventional guns, are used at Los Alamos for impact studies. The rail gun was invented here. Therefore, Los Alamos scientists have much expertise in these acceleration methods and should be able to evaluate which is best for this project.

Many things affect aiming accuracy or the ability to keep the barrel pointed in the same direction. The operator cannot hold it absolutely still. Even things as small as the operator's pulse can affect the aim. Mechanical disturbances such as the fall of the firing pin and the cycling of the action in self-loading actions also have an effect. The vibration patterns of the barrel as the weapon is fired also have an effect.

In order to compensate for operator induced errors, it is proposed to study active stabilization of the weapon. Electronic sensors will detect movements and servos will move the barrel in such a way as to compensate for these errors. To limit mechanical disturbances, it is proposed to investigate the use of an externally powered action and electrical ignition. Electrical ignition for chemically powered weapons would eliminate the firing pin fall disturbance and should give a more consistent ignition of the propellant. Since a self-loading weapon is desirable for military use, the disturbances caused by the cycling action must be eliminated. Most self-loading weapons are cycled by the firing of the cartridge. Since the power to cycle the action is only present while the projectile is in the barrel, some initial mechanical action must take place at this time and this disturbs the aim. To avoid this disturbance, it is proposed to use an externally powered action. An electric motor can be used to cycle the action. Thus, action cycling can be delayed until the projectile has left the muzzle so that disturbances of the weapon cannot affect the aim.

Barrel vibrations have a surprisingly large effect on accuracy. To minimize these vibrations, most accurate guns use extremely heavy barrels. The extra mass lessens these vibrations as well as stiffens the barrel. Even with very heavy barrels, most shooters serious about accuracy do extensive trials trying to get a combination of bullet and propellant which gives consistent vibration patterns in an individual gun. It is not uncommon to get improvements in accuracy of a factor of 3 or 4 by making minor changes in the cartridge such as slight variations in amount of powder or a change in type of primer. With an effect as great as this, it is surprising that in all the literature researched to date no one has scientifically evaluated the vibration patterns of a gun barrel or even proposed such research. An important part of this proposed research will be to measure these vibrations and develop means of minimizing their effects as well as the ability to predict the factors that cause them.

AIMING DEVICES:

All of this will not be useful if the weapon cannot be pointed properly to hit the intended target. At the proposed ranges, enhanced sights are very important. It is proposed that improvements be made in the sighting device, such as; improved magnifying optics, infra-red sensitivity, low light intensifiers, laser aiming and range sensing, and computerized range and windage compensation.

SUMMARY:

In summary, what is proposed is a systems approach using state-of-the-art computer analysis to determine the best practical combination of the above items needed to achieve the desired goal. Then the various components of the system must be developed and integrated into a complete system. All of these goals are well within the current state of the art.

Any doubt as to the effectiveness of such a weapon should be removed by trying to imagine the impossibility of trying to protect a VIP from assassination by someone armed with such a weapon. Think of having to maintain a 5000m perimeter around a military installation. Wouldn't you rather have the enemy worrying about such things instead?

The proposed program is in two phases. The initial phase to be a feasibility study as outlined below:

A computer study to determine the ballistic parameters needed to achieve the desired ranges. Then, using aerodynamic design programs, design a suitable projectile. Manufacture some of these projectiles and test them using conventional guns and cartridges. Breadboard and test the electronic systems (ie., the stabilized platform) for the weapon. Study various means of accelerating the projectile and determine the best means. Then do a preliminary design of the weapon. Systems that need evaluation will be prototyped and tested.

The initial phase of this project should take 18-24 months and require a funding level of \$625K. The funding should break down as follows:

1 man year for design, aerodynamic studies, and vibration analysis	200K
1/2 man year for manufacture and testing of projectiles	75K
1/2 man year for electronic design and testing	100K
1/2 man year for evaluating acceleration methods and weapon design	100K
Equipment, Test guns, instrumentation, and range facilities	100K
Misc material, & overhead	50K

The final phase will complete the design of the weapon with its' cartridge or other acceleration method, electronic systems, sighting system, and produce several prototype weapons. These will be extensively evaluated in laboratory and in the field and improvements made as determined necessary. Weapon manufacturers will be brought into the program at an appropriate stage to insure that, upon completion of the project, manufacture can start with minimum delay. This phase should take 24 months and between \$5 and \$10 M, depending on findings in the initial phase.

Costs of this phase should break out like this:

Finalizing the projectile and its' acceleration method	1-3M
Developing the electronic systems	1-2M
Manufacture of the prototypes	.5-1M
Sighting systems developments	1-1.5M
Equipment costs	.5M
Testing and test facilities	.5M
Misc and overhead expenses.	1-2M

Los Alamos is uniquely suited to do this work because much of the required expertise is already present. Currently, active projects here are: explosives research; impact studies using rail guns, gas guns, and conventional guns; ballistics studies (gravity bomb design); and aerodynamics (space plane and others). Additionally, one of the world's most powerful computer facilities is located here. This will make possible much more extensive computer analysis and reduce the amount of real testing required, thus reducing costs of development. Los Alamos also has sufficient secure open area to contain a firing range of the required size to suitably test the weapons.



The Original Hard Target Interdiction Concept: November 1989

I. GENERAL. The concept of Hard Target Interdiction involves engaging specified targets that are either soft skinned or lightly armored from a standoff of 1500 meters and greater. These targets would probably be strategic in nature. HTI uses a four man cell concept of highly trained individuals that are all equally qualified in long range sniping techniques. They would be infiltration specialists in either Military Freefall, Underwater Operations, or Surface Infiltration techniques.

II. HISTORICAL BACKGROUND. Throughout the modern era of warfare (World War II to present), the United States military has toyed with the idea of using large caliber weapons to engage human targets at greatly extended ranges. This has met with limited success. There were several factors at fault. Weapons systems can be faulted as well as lack of match grade ammunition. Perhaps of greater magnitude is the problems involved with the human error aspects of shooting these weapons. Some of the most well known efforts have been with the use of the Browning M2 HB machine gun with a rifle scope mounted on the weapon. This was somewhat successful. There were some kills made however, and the ranges recorded were quite long and a little difficult to believe. When one studies the weapons, ammunition, ballistics and many other factors they would have been a factor in earlier times, these long range kills become either hard to believe or a great deal of luck was involved.

II. FOUR MAN CELL CONCEPT

a. ~~The four man-cell concept involves the change from the traditional 2 man concept that is taught throughout the world. This concept works fine for a sniper team that is involved in reducing human targets at ranges out 1000 meters. The nature of training and special knowledge required to operate on the ground requires a team of a different size and composition.~~

b. There are three basic reasons why the team ^{MAY} ~~would~~ have four men

1. Extra equipment would have to be carried. Part of this is due to the ammunition requirements. 4 ea. .50 cal. rounds weigh 1 pound. Specialized range finding equipment and radio equipment would have to be carried. Therefore due to weight considerations, more men will be needed. This is the least important concern.

2. An increased level of flexibility is also available. Some of the targets may provide the opportunity for more than one heavy weapons system be employed. For example, shutting down an enemy airfield could be accomplished by employing two HTI teams. Each team will carry three weapons systems to be fired side by side. The fourth man will be the wind caller and spotter for the three weapons.

3. Security is another aspect. The nature of these operations will require that additional security be employed. The SAS of Great Britain have proven that 4 men can infiltrate and stay unnoticed for a period of time.

c. All members of the team will be heavily trained on all aspects of the concept. At times the security men will stay as security men. But if necessary they can fill in as shooter or observer. On operations where the security men are not needed for heavy weapons, they will carry standard weapons that are located within their parent unit (M-16, M-9, ect.).

d. There are some prerequisites that a member of a HTI team have before becoming an HTI team member:

- 1 SOTIC graduate. (Non-waiverable)
- 2 Special Operations Only (ARMY SF, NAVY SEALS, other DOD as necessary)
- 3 Graduate of SERE high risk (not necessary for initial training)
- 4 Prior training in Military Freefall, UWO, WIC
- 5 Submit to a diagnostic math examination.

IV. SPECIALIZED EQUIPMENT REQUIRED.

a. The successful completion of a long range interdiction mission would rely on several pieces of special equipment not normally used on sniper operations today. It should be noted that this concept is intended for be totally free of any electronic signature. This would exclude the use of radios. They would continue to be in with standard operation considerations used by SF units now. Each piece of equipment listed will have an explanation why it is needed and why it will work better than equipment currently being used.

b. Weapons. Listed below is a list of weapons and calibers currently available. The last caliber listed is not yet available in a sniper rifle but should be considered.

- 1 8.58 x 71 mm .338/.416
- 2 12.7 x 99 mm .50 cal. Browning
- 3 12.7 x 109 mm Soviet .50 Cal.
- 4 14.5 x 114 mm Soviet .57 Cal.
- 5 15.5 x 106 mm Browning MG-15 (produced by FN)

c. 8.58 x 71mm. This weapon is not intended to be used against Hard Targets. However, this weapon would be a great compliment for a HTI team in terms of security. Since it is the intention of this concept to engage hard targets at 1500m (optimum), this rifle would be used to reduce human targets that are identified as being a threat to the team. More importantly these targets are ones that located within the Hard Target complex itself. It could also be used to eliminate key operator personnel that may operate the equipment to be destroyed by the heavier weapons. An M-24 system will not reach far enough to do this. Currently this system is marketed as the M-602 by Reddick Armaments, Inc., Accuracy International (classified as the .338 Lapua Super Magnum), and other various custom gun builders.

d. 12.7 x 99mm/12.7 x 109mm. Both of these weapons will be addressed in this portion. The only difference in these weapons is that the use of the Soviet 12.7 x 109mm will address the battlefield recovery aspect of the operation.

Currently these are the 12.7 x 99 mm is the most popular caliber being used throughout special operations now. There are many weapons manufacturers with both semiautomatic and bolt action versions. I will not attempt to identify the best weapons system here without testing. In the past there was a problem with accurate enough ammunition to do the job. Currently there is match grade anti-armor ammunition available. More ammunition is being developed specifically for the HTI mission profile. The major problem with this caliber is that there is not enough energy left at 1500 meters to defeat anything more than the lightest and most delicate of hard targets. Studies of impact energy at different ranges will accompany this document.

e. 14.5 x 114mm. This is a Soviet round. This round started out as use in a Soviet antitank rifle called the PTRD. Later it was used in the KPV heavy machine gun. The only manufacturer of this weapon is Daisy Manufacturing. Several of these have been manufactured and demonstrated to USSOCOM. Once again accurate ammunition is a problem. Currently, this weapon is available from Reddick Arms Development.

f. 15.5 x 106mm. FN recently completed prototype testing of a heavy machine gun developed around this caliber. FN has decided on a completely different approach to bullet construction. They use a plastic driving band that rides the lands and grooves of the bore. This concept is not new with the exception that FN has made the plastic band longer to have more contact with the bore. They claim better accuracy. Bullet weights are between 1003 and 1204 grains with the APDS round weighing 741 grains. Muzzle velocities are between 3460 and 4395 fps. This round would greatly out perform any of the other mentioned weapons systems. Barrett Manufacturing, builders of the M82A1 semi-automatic rifle have expressed an interest in building an action around this caliber of ammunition.

g. Suppressors. All of the weapons used would be suppressed. This is not only to reduce the signature of the weapons. A problem with the large guns is muzzle blast. They all have a muzzle break of one form or another. This reduces recoil, but makes it impossible for an observer to be close to the shooter as is necessary. The use of the suppressor will allow this as well as reduce the signature of the weapons system. There are suppressors on the market that do not degrade accuracy or muzzle velocity. Another reason for the Muzzle Break/Suppressor is the amount of reflected energy the shooter is subjected to. This is due to the type of muzzle break that is currently used on most .50 caliber rifles in existence. (See Enclosure 1).

h. Theodolite. There are three reasons for the use of the theodolite as a special piece of team equipment:

1. Spotting. Due to the ranges that will be encountered a high quality optical device is needed. The scope on the theodolite is a very high grade piece of optics. Testing has shown that this device can accurately read trace and the mirage that a sniper uses to determine his wind speed and direction. The theodolite can detect minute changes in the mirage that can not be detected with even our 100mm Unertl team scopes. The device has a high power of magnification. This is necessary to observe effects on the target as well as reading the long range trace.

2. Range Determination. One of the techniques taught at SOTIC is triangulation to determine a range to a target. This is the most accurate technique. A theodolite is in surveying to measure angles. It does this very accurately and with acuity unmatched by any other method. Generally speaking, the theodolite in the hands of a practiced operator can obtain an accuracy within 3 meters at 2000 meters. This depends a great deal on the horizontal or vertical size of the target. Use of the theodolite also permits the operator to stay in one position. Standard triangulation requires the operator to move left or right 90 degrees to obtain the deflection angle. Another reason is that due to the danger space of different ammunition, the farther the range, the more accurate the range estimation has to be. For example, a 2 meter tall target at 1500 meters using Mk211-MOD-2 ammunition. This will only allow a 4.6% error in range estimation. It has been mentioned that a laser range finder may be a better choice. My argument is that the batteries are unreliable. The range finder is dependent on optimum weather conditions for its accuracy. One of the most important reasons that I do not like the laser range finder is electronic signature. Currently, the US Armed Forces is employing laser emitter detectors. They are to be placed on armored vehicles and highly secure installations. They are used to warn enemy personnel that their vehicle or site is being 'splashed' by a laser designator or laser range finder. The use of the theodolite will eliminate any danger to the team of being discovered due to electronic signature.

3. The last argument for the theodolite is that it replaces two major pieces of equipment currently in use. It replaces the observers scope with higher quality optics. It also replaces the laser range finder and provides the most accurate and dependable method of obtaining a range to the target. The theodolite is also cheaper than a laser range finder. Cost of a theodolite is between \$1500.00 and \$2500.00. This is much cheaper than a laser range finder, not even considering the cost of an observers scope.

i. Other special equipment would include a programmable calculator. This is necessary to compute changes in elevation due to altitude, temperature, barometric pressure, ect. An altimeter/barometric pressure measuring device is necessary. These can be obtained from a surveyors supply warehouse at a small cost.

V SPECIAL TRAINING REQUIRED

a. A great deal of special training will be required to field these specialty teams. Extensive training in exterior ballistics is necessary. Training in the theory and use of the theodolite is also necessary. There will be many hours of training in the 4 man cell concept and its flexible options.

b. The possibility exists that the team may have to custom load their own ammunition for certain missions. Recently reloading equipment has come on the market for the .50 Cal. weapons systems. Match grade ammunition is available.

c. Extensive training in target analysis, target identification, and priority of fires on certain systems will be given.

d. In a whole the concept of Hard Target Interdiction will require a complete retraining program for the personnel selected to be HTI specialists.

e. See Enclosure 2.

VI. COST. The cost of fielding one HTI team is relatively cheap. With the exception of the weapons and calculators, all equipment is present within the Army inventory. The theodolites are in the inventory and have an NSN assigned to the different types available. Weapons for security personnel are already within the units arms rooms. A more accurate cost analysis can be done once it is determined to what level these teams would be deployed.

VII. SUMMARY. I believe this concept has a place within US Special Operations. A letter of need for an Anti-material weapon is published. I believe that one cannot simply acquire a weapon and turn it over to a standard trained sniper and expect him to interdict a target without extensive training. Extensive testing of weapons systems available should be tested as soon as possible. This program is meant to be an interim fix until a specialized anti-material weapon can be designed and fielded.

Several units in the field are in possession of different versions of .50 caliber rifles. Most of these are still in excellent condition, although somewhat abused and greatly misunderstood. The selected optics at the time were not up to military standards. And since their initial inception, several upgrades have been directed.



.50 BMG Cartridge Tip Color Guide (Military Issue)

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
NONE	CAL 50 FA 36	DUMMY M-1	BOXER	N/A
OTHER IDENTIFYING FEATURES: Case has single hole approximately 2" up from case head and is fitted with an inert, (tinned) primer cup. NOTES: The first of the issued dummy rounds. Except for the primer color & case hole, externally identical in appearance to a standard ball round. Obvious confusion led to creation of Dummy M-2, with more features for visual identification.				
TIN	FA 40	DUMMY M-2	NONE	N/A
OTHER IDENTIFYING FEATURES: Complete round (case & projectile) stannic stained, giving it a silver or "tinned" appearance. Additionally, the primer pocket was left empty & 3 holes (rather than 1) were drilled in the case, approximately 2" up from the case head. NOTES: Significantly different in visible appearance from Dummy M-1 above. Design difficulty encountered was a tendency for the links of belted rounds to obscure the case holes. There is some disputing documentation identifying this design as M-1.				
NONE	LM 43	DUMMY M-2	NONE	N/A
OTHER IDENTIFYING FEATURES: Only the case is tinned, the projectile being left in it's natural brass color. Still 3 case holes, but moved lower (to prevent obscuring by the links). Empty primer pocket. NOTES: "Factory Second" components were used in the construction of WWII issue Dummy rounds, so headstamps are not a valid indicator of production date or assembly location.				
NONE	UT 42	DUMMY M-2	NONE	N/A
OTHER IDENTIFYING FEATURES: No projectile coloration. Brass case with 3 holes located low on the side, no case coloration. Empty primer pocket. Very heavy case mouth to projectile crimp. NOTES: Primary WWII issue. Since the cases used in the manufacture of WWII dummies are production salvage, a sealed box can contain numerous, mixed, headstamps. Projectiles used were either complete bullets or empty jackets. Due to expense (and to streamline the production process), the "tinning" process was dropped as a means of identifying Dummy ammo.				
NONE	FA 4	DUMMY M-2 (STEEL)	NONE	N/A
OTHER IDENTIFYING FEATURES: As above, but with steel, rather brass case. Original box labels will show a lot number starting with "S". NOTES: Most frequently encountered of the Dummy rounds. Still government issue today, using rounds manufactured during WWII. FA 4 headstamp is the most common. High hopes for regular production ammo using steel cases didn't work out as planned. (Steel links rubbing on steel cases created obvious corrosion hazards). These (now surplus) cases were used in Dummy production.				

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
NICKEL CLAD	FA 21	BALL M-1919	BOXER	YES
OTHER IDENTIFYING FEATURES: Typical brass case, but with cupro-nickel bullet jacket.				
NOTES: The earliest of the .50 BMG cartridges released as actual production (issue, not experimental). Headstamps from 1919 thru 1923 (including some 1924). Soon replaced by M-1923, due to inconsistent primers. NOT RECOMMENDED FOR FIRING – Collectible Grade. Most specimens exhibit case neck cracks due to lack to neck annealing.				
NONE	FA 25	BALL M-1923 (EARLY)	BOXER	YES
OTHER IDENTIFYING FEATURES: Long slender copper jacketed bullet of 790 gr., but without crimping cannellure. Early varieties headstamped from 1923 thru 1926 (including some 1927). Look for lack of projectile cannellure.				
NOTES: Designed to overcome some of the difficulties with the M-1919 round, this is the first of the mass produced rounds (over 2 million specimens in combination with M-1923 LATE). NOTE RECOMMENDED FOR FIRING – Collectible Grade, no case neck annealing.				
NONE	CAL 50 FA 29	BALL m-1923 (LATE)	BOXER	YES
OTHER IDENTIFYING FEATURES: Same as above, but with projectile crimping cannellure. Headstamps range from 1927 thru 1929 (including some 1930).				
NOTES: Identical in all respects to above, except for the US Army Ordnance Office mandated projectile crimping cannellure (to prevent accidental projectile setback during handling & firing). NOT RECOMMENDED FOR FIRING – Collectible Grade, no case neck annealing.				
NONE	CAL 50 FA 32	BALL M-1	BOXER	YES
OTHER IDENTIFYING FEATURES: Superficially identical to M-1923 (LATE) round, but with shorter 750 grain projectile. Headstamps range from 1931 to 1940 (including some 1941).				
NOTES: Designed to produce shorter time of flight and higher velocities, BALL M-1 was intended to replace M-1923 series.				
NONE	WRA * 50 *	BALL M-2	BOXER	YES
OTHER IDENTIFYING FEATURES: Similar to BALL M-1, with slightly smaller projectile length and different tip, also 40 grains lighter. Some have smooth projectile crimping cannellure, some knurled, some also sport knurled ID cannellure. Headstamped 1941 thru 1950.				
NOTES: Shorter time of flight, higher muzzle velocities than M-1. Primary WWII issue, production in hundreds of millions. Produced by nearly every US arsenal, ordnance plant, and private ammo manufacturer. The presence of stars in the headstamp indicate an experimental extruded case.				

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
NONE	RA 52	BALL M-33 (EARLY)	BOXER	NO
OTHER IDENTIFYING FEATURES: Physically similar to Ball M-2, but most have knurled projectile ID cannellure. Headstamps start in 1951. Refer to box labels for lot numbers to verify type.				
NOTES: Lighter still (650 gr.) than M-2 Ball, developed to ballistically match M-8 API with correspondingly higher muzzle velocities. Initial production with corrosive primers which, depending on manufacturer, switched to non-corrosive by 1953.				
NONE	WCC 90	BALL M-33 (LATE)	BOXER	NO
OTHER IDENTIFYING FEATURES: M-33 (LATE) differs from M-33 (EARLY) only in the absence of the projectile ID cannellure.				
NOTES: Projectile weights 650-665 grains. Muzzle velocities are 2910 fps (machine gun barrel). (M-2 Ball 710 gr., 2810 fps).				
NONE	FA 41	HPT (PROOF) M-1	BOXER	YES
OTHER IDENTIFYING FEATURES: Projectile appearance of a "BALL" loading, but with nickel colored brass case. (Actually stannic stained).				
NOTES: **UNDER NO CIRCUMSTANCES TO BE FIRE** Intended to proof test gun receivers only! Hi pressure test round develops significantly higher than normal chamber pressures, using 1000 gr. dual-lead cored projectile. WWII headstamps most frequently encountered, although specimens headstamped at late as 1983 known. Corrosivity dependent on manufacturing date.				
NONE	CAL 50 FA 27	TRACER M-1923	BOXER	YES
OTHER IDENTIFYING FEATURES: Projectile appearance of a "BALL" loading, but with blackened brass case. Headstamps range from 1923 through 1928 (including a few 1929).				
NOTES: The first of the issued tracer rounds for the .50 BMG. NOT RECOMMENDED FOR FIRING – Collectible Grade. Unstable tracer compounds (rapid storage deterioration), frequently encountered case neck cracks (no annealing of the necks).				
RED TIP	FA * 42	TRACER M-1	BOXER	YES
OTHER IDENTIFYING FEATURES: Initial production in 1929 still identified like TRACER M-1923. Red tip was adopted in 1930. Headstamps thru 1945 are known, those with a star in the headstamp indicate a special "high anneal" case.				
NOTES: Steady red trace from 250 ft to 1600 yards. Production problems ranged from lack of trace, to case neck cracks. NOT RECOMMENDED FOR FIRING – Considerable experimentation done from increasing storability of tracer composition, to case neck annealing.				

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
RED TIP	DM 43	TRACER M-1 (ALTERNATE)	BOXER	YES
OTHER IDENTIFYING FEATURES: Identical in all respects to Tracer M-1, but with gilding metal clad steel (GMCS) projectile jacket. (Projectile will attract a magnet along its entire length.) Headstamps from 1942 thru end of WWII.				
NOTES: Developed to reduce the amount of copper (critical war material) in ammo production. Loaded to slightly higher muzzle velocities due to lighter projectile weight (copper clad steel, rather than pure copper jacket). NOT RECOMMENDED FOR FIRING – similar problems encountered with TRACER M-1.				
RED TIP	LC 4	TRACER M-21 (HEADLIGHT)	BOXER	YES
OTHER IDENTIFYING FEATURES: Externally, identical to TRACER M-1 (Alternate). Box labels the only reliable method of identification besides destructive analysis & live firing. Projectile is loaded with ignitor compound only, instead of tracer & ignitor pair as in other tracer ammo.				
NOTES: Called "Headlight" because, unlike most tracers, this one's trace is visible to not only the shooter, but THE TARGET AW WELL. Intended for air-to-air engagements, it was hoped the sight of oncoming balls of light would disrupt the enemy's attack. NOT RECOMMENDED FOR FIRING – Collectible Grade. Case neck cracks & tracer storage problems.				
RED TIP	FA 45	TRACER M-21 (ALTERNATE)	BOXER	YES
OTHER IDENTIFYING FEATURES: Externally identical to Tracer M-1 (Alternate). Different from TRACER M-21 above in that this one has a gilding metal clad steel projectile jacket instead of gilding metal alone. Refer to box label for identification.				
NOTES: Same as M-21 above. NOT RECOMMENDED FOR FIRING – Collectible Grade. Case neck cracks & tracer compound deteriorates with storage. M-21 Tracer family first begun in 1943.				
PINK TIP	SL 43	TRACER (M-1? M21?)	BOXER	YES
OTHER IDENTIFYING FEATURES: Known on in this headstamping. Externally identical to all other tracers of this era, except for this strange tip color.				
NOTES: Definitely a tracer of some kind. Unknown whether this is an M-1 with poor shade of red, or some type of Headlight tracer. Consequently, NOT RECOMMENDED FOR FIRING.				
WHITE TIP	FA 42	TRACER M-2	BOXER	YES
OTHER IDENTIFYING FEATURES: Projectile has a knurled ID cannellure. Headstamps only from 1941 thru 1943.				
NOTES: Designed to replace TRACER M-1 based on British information recommending short range tracers. Later replaced itself by Tracer M-10 (dim/bright trace) & then M-17 (long range trace), NOT RECOMMENDED FOR FIRING – Collectible Grade.				

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
GREY TIP	FA 43	TRACER T-12	BOXER	YES
OTHER IDENTIFYING FEATURES: 1943 headstamped only. Gilding metal projectile jacket.				
NOTES: Just after beginning work on a short range tracer, the US received word from Britain that a dim/bright tracer was even better & the Air Corps began work on this concept, tested as the T12. Later leading to adoption as M-10 for air use only. NOT RECOMMENDED FOR FIRING – Collectible Grade, production limited, developmental only. RARE and highly desirable as a collectible.				
ORANGE TIP	DM 4	TRACER M-10	BOXER	YES
OTHER IDENTIFYING FEATURES: Knurled projectile ID cannellure. Headstamped from 1943 through 1945. Both gilding metal and bilding metal clad steel projectile jackets were used. The latter is most frequently encountered.				
NOTES: The adopted version of the T12 above, for field issue. Utilized for aircraft only. Designed to prevent night blindness of the gunners, the projectile traces dim out to 150 yards, then turns bright. NOT RECOMMENDED FOR FIRING, usual WWII era tracer problems.				
ORANGE TIP	FA 45	TRACER M10E1	BOXER	YES
OTHER IDENTIFYING FEATURES: Visibly identical to M-10 above, except for green primer sealant. Known in this headstamp only.				
NOTES: Designed as a companion round to the INCENDIARY M1E1 and API M8E1, intended to reduce time of flight for better air-to-air accuracy (3100 fps vs 2900 fps). NOT RECOMMENDED FOR FIRING – Collectible Grade. Limited production, erratic pressures, excessive muzzle flash & bore erosion, as well as typical WWII era tracer problems. RARE, highly desirable as a collectible.				
MAROON TIP	WRA 51	TRACER M-17 (EARLY)	BOXER	YES
OTHER IDENTIFYING FEATURES: Some specimens sport the optional knurled ID cannellure on the projectile. Gilding metal clad steel projectile jackets. Headstamps from 1943 until around 1951.				
NOTES: Known as the T9 during development, the M-17 was produced at the request of the Anti-Aircraft Command in 1942 to have a .50 tracer to match other caliber AAA guns. The so-called long range tracer (to 2500 yards). Tip color changed to dark brown about the time of adoption of non-corrosive primers (direct cause unknown). Better tracer storability.				
BROWN TIP	LC 85	TRACER M-17 (LATE)	BOXER	NO
OTHER IDENTIFYING FEATURES: Gilding metal clad steel jacket. Most production has knurled projectile ID cannellure.				
NOTES: Except for tip color, identical to M-17 (EARLY). Most production after about 1951 utilize non-corrosive primers. Developed originally for ground use only, now current issue tracer in use by both air & ground weapons. Depending on lot and manufacturer, tip colors between M-17 LATE and EARLY are difficult to tell apart.				

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
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GREEN TIP WRA 55 TRI-PLEX BOXER NO

OTHER IDENTIFYING FEATURES: Only known in this headstamp.

NOTES: .50 caliber equivalent to 7.62 NATO M-198 Duplex round. Three conventional projectiles loaded nose to tail (only 1st of which is visible). Listed muzzle velocity: 2550 fps. Never adopted. NOT RECOMMENDED FOR FIRING – Collectible Grade, Extremely Rare, limited test production.

GREEN TIP LC 81 MULTI-PURPOSE BOXER NO

OTHER IDENTIFYING FEATURES: Headstamps most frequently encountered: LC 81, WCC 84, Headstamps start with 1980s.

Smooth projectile crimping cannellure.

NOTES: Raufoss design Hi Explosive-Incendiary-Armor Piercing (HEIAP) round. Otherwise known as Multi-Purpose (MP) or Pyrotechnically Initiated Explosive (PIE). Chemical reaction on impact, rather than mechanical fuze, initiates the explosion. Reportedly no longer produced by WCC. 665 grain projectile @ 2970 fps (depending on the gun system) (See Green/Silver Tip).

GREEN HOLLOW POINT FA 43 HE-CN BOXER YES

OTHER IDENTIFYING FEATURES: Slightly recessed tip in projectile with knurled ID cannellure. Known only in this headstamping.

NOTES: Hi Explosive-Tear Gas round. For cave fighting & air-to-air, never mass produced. Insufficient effect inside caves & the comparatively breezy fuselages of WWII aircraft. 580 grain projectile. (See also Green/Black tip) NOT RECOMMENDED FOR FIRING – Collectible Grade

GREEN TIP RA 1941 CAL 50 Z ARMOR PIERCING BOXER YES

OTHER IDENTIFYING FEATURES: Usually includes nickel primer with matching green primer sealant. Headstampings 1940, 41 & possibly 1942.

NOTES: Remington Arms produced under British contract for World War II Lend-Lease. "Z" in the headstamp denotes non-cordite powder charge. Typical M-1 Armor Piercing projectile, but with British (pre-NATO) color code for AP. NOT RECOMMENDED FOR FIRING – Collectible Grade.

OLIVE DRAB TIP FA 44 APIT T-28 BOXER YES

OTHER IDENTIFYING FEATURES: Known only in this headstamp.

NOTES: First of the Armor Piercing-Incendiary-Tracers, predecessor to APIT M-20. (See Red/Silver & Silver/Red Tip) NOT RECOMMENDED FOR FIRING – Collectible Grade, limited production, extremely rare.

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
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BLACK TIP FA 52 DUMMY XM-176 BOXER N/A

OTHER IDENTIFYING FEATURES: Completely blackened brass case & projectile. Inert loaded to proper weight with powder simulat. Very heavy case crimp to retain projectile. Known only in this headstamp.

NONE: .50 caliber equivalent to 7.62 NATO M-172 Dummy. Never adopted. Rare-Collectible Grade.

BLACK TIP CAL 50 FA 26 AP M-1923 (EARLY) BOXER YES

OTHER IDENTIFYING FEATURES: Lack of projectile cannellure. Headstamps range from 1923 to 1927.

NOTES: The first of the issued Armor Piercing rounds. Differs from M-1923 (LATE) only in the absence of the (later) mandated projectile crimping cannellure. JExceptionally long & heavy projectile for the .50 cartridge (810 grains). Listed muzzle velocity: 2550 fps. NOT RECOMMENDED FOR FIRING – No case neck annealing, Collectible Grade.

BLACK TIP CAL 50 FA 28 AP M-1923 (LATE) BOXER YES

OTHER IDENTIFYING FEATURES: Carries projectile crimping cannellure. Headstamps range from 1927 to 1928.

NOTES: See notes for AP M-1923 (EARLY). NOT RECOMMENDED FOR FIRING – no case neck annealing. Collectible Grade.

BLACK TIP CAL 50 FA 35 AP M-1 BOXER YES

OTHER IDENTIFYING FEATURES: Headstamps range from 1929 to 1940, some 1941.

NOTES: Projectile is considerably smaller & lighter than AP M-1923 series (750 grains). Higher muzzle velocities (2650 fps), faster time of flight, flatter trajectory. Designed to match the trajectory of Ball M-1.

BLACK TIP M 43 AP M-2 BOXER YES

OTHER IDENTIFYING FEATURES: Early versions were given an (optional) knurled ID cannellure to differentiate them from AP M-1 production identical in appearance to AP M-1 in all other aspects. Headstamps from 1941 to the end fo WWII.

NOTES: With the perfection of the API M-8, AP production was cancelled after WWII. (API being capable of all standard AP roles.) M-2 projectile slightly smaller & lighter than M-1 (710 grains). Created to ballistically match BALL M-2. (Higher muzzle velocity – 2900 fps).

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
BLUE TIP	DM 43	INCENDIARY M-1	BOXER	YES
OTHER IDENTIFYING FEATURES: Large, heavy projectile ID cannellure utilized to retain internal components. Headstamps start in 1941.				
NOTES: Rushed into production during WWII, this design replaced that of Remington. High demand & production difficulties resulted in adoption of other designs as well. Incendiaries eventually replaced by API M-8 series. 630 grain projectile, 3000 fps. (See also Dark Blue/Blue tip).				
BLUE TIP	RA 42	INCENDIARY M-1 (ALTERNATE)	BOXER	YES
OTHER IDENTIFYING FEATURES: Known only in this headstamp. Thin, smooth, projectile ID & crimping cannellures.				
NOTES: The first of the major .50 cal Incendiary designs. Later classified as "Alternate" with the adoption of the design above. Remington design 645 grain flat base projectile. NOT RECOMMENDED FOR FIRING – collectible Grade, limited production.				
BLUE TIP	U 42	INCENDIARY M-1 (ALTERNATE)	BOXER	YES
OTHER IDENTIFYING FEATURES: Known only in this headstamp. Thin, smooth, projectile ID cannellure; knurled crimping cannellure.				
NOTES: The first of the major attempts to solve production difficulties with the .50 Incendiary design. (See also Dark Blue/Blue tip). Utah Ordnance Plant design, without steel internal sleeve (projectile will not attract a magnet). 628 grain projectile, 3300 fps. NOT RECOMMENDED FOR FIRING – Collectible Grade, limited production.				
BLUE TIP	FA 45	INCENDIARY M1E1	BOXER	YES
OTHER IDENTIFYING FEATURES: With green primer sealant, & known only in this headstamping. In all other regards, visibly identical to Incendiary M-1.				
NOTES: Designed to shorten time of flight, higher muzzle velocity, flatter trajectory. Intended as mate to TRACER M1E1 & API M8E1, the higher velocity .50s. Hi levels of muzzle flash and bore erosion led to it's abandonment. Muzzle velocity: 3100 fps. (See also Dark Blue/Blue tip.) NOT RECOMENDED FOR FIRING-HAZARDOUS. Collectible Grade, RARE.				
BLUE TIP	WCC 36	LRT	BOXER	NO
OTHER IDENTIFYING FEATURES: Blue to indicate inert/training ordnance rather than Incendiary. Blue tips from WCC (OLIN) & AAI. Some AAI specimens have completely blue projectiles. Headstampings start in 1970s & don't necessarily indicate date or manufacturer.				

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
NOTES: Limited Range Training or Short Range Training Ammunition (SRTA). Designed to fall out of the air after traveling a short distance. Most utilize a finned tail section to create rotational drag. For use on smaller European training ranges. Some tips appear almost purple in coloration. NOT RECOMMENDED FOR FIRING – Presently Collectible Grade				
SILVER TIP	FA 40	AP PLATE TEST M-1	BOXER	YES
OTHER IDENTIFYING FEATURES: Physically identical in appearance to API M-8. Headstamps range from 1940 to 1941.				
NOTES: Silver tip color coding originally intended to indicate "Non-Standard Load". (Silver tips after 1942 indicate Armor Piercing-Incendiary ammunition). Armor Piercing Plate Test rounds are essential AP ammunition loaded with varying powder charges to test the resistance or armor plate. NOT RECOMMENDED FOR FIRING – HAZARDOUS. (See also Black/Silver & Silver/Black tip).				
SILVER TIP	45 TW	API M-8	BOXER	BOTH
OTHER IDENTIFYING FEATURES: Physically identical in appearance to AP PLATE TEST M-1 (above). Headstamps from 1943 to current.				
NOTES: Initial Armor Piercing-Incendiary production (color coded Blue/Black), was changed to silver in 1943. Primer corrosivity dependant upon production date & location. (Generally, corrosive till 1953.) 660 grain projectile @ 2900 fps. See Blue/Black & Blue/Silver tip listings.				
SILVER TIP	FA 45	API M8E1	BOXER	YES
OTHER IDENTIFYING FEATURES: With green primer sealant & known only in this & FA 4 headstamp. In all other regards, visibly identical to API M-8.				
NOTES: Designed to be matched to TRACER M10E1 & INCENDIARY M1E1. The family of higher velocity .50s. Hi levels of muzzle flash & bore erosion led to their abandonmnet. Muzzle velocity: 3100 fps. NOT RECOMMENDED FOR FIRING – HAZARDOUS, Collectible Grade, limited production, RARE (See also Blue/Silver tip).				
BLUE/BLACK TIP	FA 43	API T-16	BOXER	YES
OTHER IDENTIFYING FEATURES: Known only in this headstamp. Knurled ID cannellure on projectile.				
NOTES: Initial color code for API M-8. Changed to silver within a year. NOT RECOMMENDED FOR FIRING – Collectible Grade, VERY limited production.				
RED/SILVER TIP	TW 53	APIT M-20	BOXER	BOTH
OTHER IDENTIFYING FEATURES: Smooth crimp cannellure on projectile. Can also hve knurled, smooth, or no ID cannellure. Headstamps 1945 to present.				

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
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NOTES: Current issue Armor Piercing-Incendiary-Tracer. 620 grain projectile propelled to 3000 fps. (See Silver/Red tip). Primer corrosivity dependant on production date & location (Generally, corrosive till 1953.)

SILVER/RED TIP FA 46 APIT T63 BOXER YES

OTHER IDENTIFYING FEATURES: Knurled ID cannellure on projectile. FA headstampings from 1944-47. (Compare tip colors to APIT M-20).

NOTES: Part of the "Super Incendiary" series of light weight (500 gr), high velocity (3400 fps) .50s. Intended for air to air use replacing APIT M-20 (shorter time of flight). Mate to M-23 (BLUE/BLUE) Incendiary & T49 (Blue/Silver) API. NOT RECOMMENDED FOR FIRING - Collectible Grade, Extremely limited production.

DARK BLUE/BLUE TIP TW 4 INCENDIARY M-23 BOXER BOTH

OTHER IDENTIFYING FEATURES: Smooth or knurled projectile crimp cannellures, may also have knurled ID cannellure. Headstampings from 1944 to mid-1950s. Assembly plants LC, FA, DM, SL & TW. Known during development as T48.

NOTES: The only member of the "Super Incendiary" series to reach "M" class adoption. Intended as a mate to the T63 (SILVER/RED) APIT y T49 (BLUE/SILVER) API; the light weight (500 grain), hi velocity (3400 fps) .50s. Intended for air to air use (shorter time of flight) replacing the M-1 Incendiary. NOT RECOMMENDED FOR FIRING - Collectible Grade, Limited Production.

BLUE/SILVER TIP FA 45 API T49 BOXER YES

OTHER IDENTIFYING FEATURES: Known only with smooth crimping cannellure on projectile. Only known headstamp besides FA 4.

NOTES: Also part of the "Super Incendiary" series of light weight 9500 grain), hi velocity (3400 fps) .50s. Intended for air to air use replacing API M-8 (shorter time of flight). Mate to the T63 (SILVER/RED) APIT & M-23 (BLUE/BLUE) Incendiary. NOT RECOMMENDED FOR FIRING - Collectible Grade, Extremely limited production.

GREEN/SILVER TIP WCC 87 MP Mk 211, Mod-0 BOXER NO

OTHER IDENTIFYING FEATURES: Known only with smooth crimping cannellure. Headstampings start mid-1980s. Some LC (US) and HXP (Greece) headstamps reported. Potentially also IVI (Canada) & EMZ (Dutch) headstamps.

NOTES: US Navy contract Raufoss (Norway) design PIE (Pyrotechnically Initiated Explosive), MP (Multi-Purpose), or HEIAP (Hi-Explosive Incendiary-Armor-Piercing). Some loadings by OLIN (WCC), most by Raufoss using cases purchased in other countries. 665 grains projectile at 2970 fps (29" barrel). NOT RECOMMENDED FOR FIRING - Collectible Grade (at present), Limited Production.

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
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SILVER/GREEN TIP LC 86 **UNKNOWN** BOXER NO

OTHER IDENTIFYING FEATURES: Knurled, rather than more commonly encountered smooth projectile crimp cannellure.

NOTES: Reportedly Navy Raufoss Multi-Purpose Mk. 211, Mod-0. Like GREEN/SILVER (see above). Projectile weight, cannellure, and configuration more like painted M-33 Ball (650 grain). Consequently, NOT RECOMMENDED FOR FIRING.

GREEN/BLACK TIP FA 43 APCN BOXER YES

OTHER IDENTIFYING FEATURES: Knurled projectile ID cannellure. Only known in this & possibly FA 44 headstamp.

NONE: 647 grain Armor Piercing-Tear Gas from pfojects for air to air combat & Pacific cave fighting. (See GREEN HOLLOW POINT.) NOT RECOMMENDED FOR FIRING - Collectible Grade, Limited Production.

YELLOW/BLACK TIP FA 62 **UNKNOWN** BOXER NO

OTHER IDENTIFYING FEATURES: Two knurled ID cannellures on projectile. Only headstamp yet identified.

NOTES: Projectile internal configuration indicates may have been intended as a replacement for AP or API. Yellow color coding usually reserved for HE or HEI (APHE loading?). Exact details are lacking. Consequently, NOT RECOMMENDED FOR FIRING-Collectible Grade.

YELLOW/BLUE TIP FA 4 HEI T34 BOXER YES

OTHER IDENTIFYING FEATURES: Knurled ID cannellure on projectile. Only known headstamping.

NOTES: Intended as a replacement for M-1 Incendiary. Greater incendiary effects on impact. Project abandoned due to unresolved cook-off problems. May not be bore safe/drop safe. NOT RECOMMENDED FOR FIRING - Potentially Hazardous - Collectible Grade.

YELLOW/RED HOLLOW POINT FA 60 SPOTTER-TRACER XM156 BOXER NO

OTHER IDENTIFYING FEATURES: Most common headstamp, possibly also FA 59 & other early FA 60s dates. Knurled crimp cannellure, no ID cannellures. Slightly recessed tip, holding detonating primer. (Circa 1962).

NOTES: 830 grain .50 BAT (or .50 Short) M48A1 Spotter-Tracer projectile in BMG case, modified with primer flash tube. Projectile contains small smoke & HE charges as well as tracer element. Interim Shilleleigh weapon spotting cartridge for XM121 MG, 1:12" rifling, 2496 fps. 8,000 cartridges were produced. NOT BORE/DROP SAFE-NOT RECOMMENDED FOR FIRING - Collectible Grade.

RED/BLUE TIP FA 58 SPOTTER-TRACER BOXER NO

OTHER IDENTIFYING FEATURES: Only known headstamping. Knurled crimping cannellure (only). White primer sealant.

NOTES: Long range spotter-tracer for tank machine guns, used to synchronize aim of main gun. (A major use for the BMG cartridge in UK. Projectile FAT86E3. NOT RECOMMENDED FOR FIRING - Collectible Grade, Limited Production.

PROJECTILE COLORATION	TYPICAL HEADSTAMP	ROUND TYPE	PRIMER DESIGN	CORROSIVE (Y/N)
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SILVER/BLACK TIP **FA 41** **ARMOR PLATE TEST M-2 (EARLY)** **BOXER** **YES**
OTHER IDENTIFYING FEATURES: With or without projectile ID cannelure. Factory loads FA 41 headstamps only. Factory packaged selected lots of these AP M-2 projectiles for outside source loadings may have any headstamp. Compare tip colors with BLACK/SILVER.
NOTES: Black tipped AP M-2 projectiles over-dipped silver to indicated non-standard AP loadings. Multiple lots loaded to various pressure levels & muzzle velocities to test armor plate resistance to .50 caliber projectiles. **NOT RECOMMENDED FOR FIRING – Potentially Hazardous pressures – Collectible Grade.**

BLACK/SILVER TIP **FA 53** **ARMOR PLATE TEST M-2 (LATE)** **BOXER** **UNKNOWN**
OTHER IDENTIFYING FEATURES: Only known headstamping. (Compare with SILVER/BLACK AP TEST).
NOTES: Same as SILVER/BLACK TIP AP TEST M-2 (EARLY). Note tip color reversal. **NOT RECOMMENDED FOR FIRING – Potentially Hazardous pressures – Collectible Grade.**

GREEN/RED TIP **FA 31** **RANGING TRACER T7E1** **BOXER** **YES**
OTHER IDENTIFYING FEATURES: FA headstampings from 1931 through 1934. Projectile weight is 682 grains.
NOTES: Developed for the Coast Artillery for determine distance to target. Tracing green from muzzle to approximately 1200 yards, then changing to red out to 2500 yards from the gun position. Only 32,000 produced and issued. Limited shelf life (3.5 years) due to decomposition of igniter mixture. Consequently, **NOT RECOMMENDED FOR FIRING – Collectible Grade.**

RED TIP **CAL 50 FA 34** **DELAY TRACER** **BOXER** **YES**
OTHER IDENTIFYING FEATURES: A two-tone tip without a forward color; a red-banded projectile. Knurled crimping cannelure, no ID cannelures. FA headstamps from 1932-1938.
NOTES: Also for the Coast Artillery, a tracer that wouldn't blind the gunner at night. Concept known as "Dark Ignition" in UK. Tracer elements burn but don't become visible till well after leaving the muzzle. Production also suspended due to ignitor mixture decomposition. **NOT RECOMMENDED FOR FIRING – Collectible Grade, Limited Production.**

Data Credits to: History of Modern US Military Small Arms Ammunition (Vol I & II), Woodlin, Scranton, Hackley.
Data compiled for Very High Power Magazine by Keith Pagel, Staff Writer, VHP Magazine.

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